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THE PACIFIC MAIL STEAMSHIP *KOREA*.

BY LIEUTENANT CHARLES K. MALLORY, U. S. N.

The new 18,000-ton steamer *Korea*, built at the works of the Newport News Shipbuilding and Drydock Company, Newport News, Va., for the Pacific Mail Steamship Company, has completed a successful trial, during which it is estimated that a speed of 20 knots was obtained; the contract called for 18 knots, but the builders expected to exceed this amount.

The *Korea* and her sister ship, the *Siberia*, the latter not yet completed, are intended for both passenger and freight traffic on the line between San Francisco and ports of China and Japan.

In the design of these ships especial attention has been given to sanitary arrangements and the comfort of the passengers, two important items in vessels making the long run across the Pacific. Accommodations are provided for 220 first-class passengers; 54 white steerage, and 1,144 Chinese; should the latter not be carried, the unoccupied space will be used for additional cargo.

Provisions are made for the ship's complement as follows:

Nine deck officers, 10 engineers, 41 deck hands, 111 in engineer's force, and 63 stewards.

There are six principal decks; the top, called the boat deck, carries one 24-foot and eleven 28-foot lifeboats and a deck house in which are quarters for the ship's officers.

The next deck, between the forward and after wells, is known as the promenade deck, while the extension forward forms the forecastle, and aft, the poop.

The social hall, smoking room, music room and some of the first-class cabins are located on the promenade deck.

Below the promenade is the upper deck, extending the full length of the ship; on this are the remainder of the first-class cabins, the dining saloon, galley and pantry, lavatories, bath rooms, crew's quarters and steering-engine room.

On the next, the main deck, are the quarters for the steerage passengers, the baggage room, coal bunkers, donkey-boiler room, dynamo room, workshop, cold storage and refrigerator rooms.

Next below the main is the lower deck; on this are the rooms for the forced-draft ventilator fans, and coal bunkers, while the remainder is devoted to cargo.

That part of the orlop deck and hold not in wake of engine and fire rooms, is utilized for cargo space, fresh water and trimming tanks.

Four stockless anchors with 330 fathoms, 3-inch stud link, and 120 fathoms, $1\frac{9}{16}$-inch, stream chain are carried; the anchor weights are 15,294, 13,215, 4,052 and 2,196 pounds.

GENERAL DIMENSIONS.

Length over all, feet and inches	572-4
between perpendiculars, feet and inches	550-0
Breadth, extreme, feet and inches	63-0
Depth, molded, feet and inches	40-0
Gross tonnage	11,276
Net tonnage	5,621
Displacement at 27 feet draught, tons	18,400
Area immersed midship section, square feet	1,643
wetted surface, square feet	51,000
Number of transverse water-tight bulkheads	16
masts	2
smoke pipes	2
Material of hull	Mild steel.
Frame spacing, inches	32

MAIN ENGINES.

The main engines are of the vertical, inverted, direct-acting, four-cylinder, quadruple-expansion type, each located in a separate watertight compartment.

The cylinder arrangement, beginning from forward, is as follows: H.P., L.P., 2d M.P. and 1st M.P.

The H.P. and L.P. cranks are opposite; also the first and second M.P., the latter pair being at right angles to the former. The crank sequence is: H.P., 2d M.P., L.P. and 1st M.P.

The engine bed, consisting of cross girders of cast steel, is made in four sections, each carrying two main bearings, and the whole bolted rigidly together.

The framing is made up of sixteen cast-steel columns of I section, each bolted to the engine bed, and, at the top, to the adjacent one on same side, thus forming on each side of engine a continuous girder.

The cylinders are bolted to the upper ends of the columns, but are not secured to each other, being left free to expand independently. Their centers are, however, kept in the same fore-and-aft line by means of vertical guide bars bolted on both sides of one cylinder and bearing on machined surfaces of the adjacent one.

The valves are all of the single-ported piston type, there being one for each high-pressure cylinder, two for each first and second intermediate pressure and four for each low-pressure cylinder. They are fitted with spring rings and followers. The H.P. and 2d M.P. take steam at center, and the 1st M.P. and L.P. at the ends. Balance pistons are fitted for each valve, the cylinders for pistons forming part of valve-chest cover. The link motion is of the double-bar Stephenson type, each link being fitted into an independent adjustable cut-off block.

The H.P. valve stem takes hold of the link block direct, while the others are fitted with a cast-steel crosshead for each pair.

The link blocks are of cast steel, the eccentrics of cast iron and the eccentric straps of cast steel lined with white metal. The eccentrics are keyed to the main shaft, except the 2d M.P. and the forward pair for the L.P., which are keyed to the outer

circumference of shaft couplings. The key ways in the eccentric sheaves are wider than the key itself, side keys being fitted to permit adjustment. One key secures both eccentrics, but the ahead and backing for those on couplings are secured to each other by through bolts.

Working liners of hard cast iron are fitted in all main cylinders. Cylinders are steam jacketed around the liners and at both ends, except the H.P.

The main pistons are of cast steel, dished. They are made a taper fit in piston rods and secured by a nut. A collar on rod bears on under side of piston.

Each piston has a cast-iron follower in which, for the H.P. and 1st M.P. are fitted three, and for the 2d M.P. and L.P. two split packing rings of cast iron.

The crossheads are of forged steel, of double T section, made a taper fit on piston rods and secured by a nut; there are bolted to each, four slippers with white-metal wearing surface, two for ahead and two for backing; each of these works on a cast-iron guide secured to one of the engine columns.

There is a steam, float-lever reversing gear, fitted with hydraulic control cylinder, which may also be operated by a hand pump; one piston rod serves for both steam and hydraulic pistons.

A two-cylinder turning engine is secured to each engine bed on outboard side and operates by means of shafting fitted with worm gearing.

The throttle valve is of the balanced type, fitted with a by pass and operated, through levers, by means of a wheel at the working platform; the opening of throttle is also controlled by a Westinghouse governor which gets its motion from main shaft through a sprocket chain. Connections are made for admitting steam to the receivers.

The main steam pipes are of seamless drawn steel; the receiver pipes of copper. The cylinder lagging is held in place by sheet-iron covering.

The L.P. piston is extended to form a tail rod working through a stuffing box in cylinder cover.

Metallic packing is used in stuffing boxes of piston rods and valve stems.

DATA FOR ONE MAIN ENGINE.

Cylinders, number	4
H.P., diameter, inches	35
1st M.P., diameter, inches	50
2d M.P., diameter, inches	70
L.P., diameter, inches	100
Stroke of pistons, inches	66
Valves, piston, H.P. (1), diameter, inches	20
1st M.P. (2), diameter, inches	17
2d M.P. (2), diameter, inches	28
L.P. (4), diameter, inches	25
Balance pistons, H.P., diameter, inches	7½
1st M.P., diameter, inches	7½
2d M.P., diameter, inches	15
L.P., diameter, inches	15
Valve stems, H.P., 1st M.P., 2d M.P. and L.P., diameter, inches	3¼
diameter, through valve, inches	3
Main steam pipe (1) 13 inches diameter, area cross section, square inches	132.733
Exhaust pipe to 1st M.P. cylinder (1) at H.P. cylinder, 16 inches diameter, area cross section, square inches	201.062
Exhaust pipe to 1st M.P. cylinder (1) at 1st M.P. cylinder, 21 inches diameter, area cross section, square inches	346.361
Exhaust pipe to 2d M.P. cylinder (2), 20 inches diameter, area cross section, square inches	628.320
Exhaust pipe to L.P. cylinder (4), 14½ inches diameter, area cross section, square inches	660.520
Exhaust pipe to main condenser (2), 24 inches diameter, area cross section, square inches	904.780
Volume swept by H.P. piston, mean, per stroke, cubic feet	35.79
1st M.P. piston, mean, per stroke, cubic feet	74.04
2d M.P. piston, mean, per stroke, cubic feet	146.03
L.P. piston, mean, per stroke, cubic feet	299.02
Net area, 1st M.P. to H.P. piston	2.04
2d M.P. to 1st M.P. piston	1.96
L.P. to 2d M.P. piston	2.04
2d M.P. to H.P. piston	4.00
L.P. to 1st M.P. piston	4.00
L.P. to H.P. piston	8.163
Clearance of H.P. cylinder, per cent	top, 19.75; bottom, 24.20
1st M.P. cylinder, per cent	top, 19.55; bottom, 22.60
2d M.P. cylinder, per cent	top, 15.04; bottom, 18.22
L.P. cylinder, per cent	top, 14.80; bottom, 15.90

Piston rods, diameter, parallel part, inches	8
length, parallel part, feet and inches	8–8½
diameter in piston, inches	6
diameter in crosshead, inches	7½
diameter in collar under piston, inches	10
Tail rod, L.P., diameter, inches	5½
Thickness cylinder walls, H.P. and 1st M.P., inches	1⅝
2d M.P. and L.P., inches	1¾
liners, all, inches	1½
ends, all, inches	1½
valve liners, all, inches	1½
Jacket space, H.P., 1st M.P. and 2d M.P., inch	⅝
L.P., inch	1
Piston face, all, depth, inches	8
Piston, H.P. and 1st M.P., total depth, inches	19½
2d M.P. and L.P., total depth, inches	25½
Valve cut-off, H.P., per cent	top, 75 ; bottom, 69.3
1st M.P., per cent	top, 77.65 ; bottom, 74.32
2d M.P., per cent	top, 74.2 ; bottom, 66.8
L.P., per cent	top, 75 ; bottom, 69.1
Area port opening, H.P., steam, square inches	top, 123.7 ; bottom, 143.5
1st M.P., steam, square inches	top, 220 ; bottom, 252.5
2d M.P., steam, square inches	top, 349.2 ; bottom, 381.6
L.P., steam, square inches	top, 650.8 ; bottom, 746.4
H.P., exhaust, square inches	176.5
1st M.P., exhaust, square inches	300
2d M.P., exhaust, square inches	495
L.P., exhaust, square inches	885
Cylinder relief valves, H.P. (1), 1st M.P. (1), diameter, inches	3½
2d M.P. (1), L.P. (2), diameter, inches	4½
Receiver safety valves, all, diameter, inches	3½
Connecting rods, length, center to center, inches	138
diameter upper end, inches	7½
middle, inches	8½
lower end, inches	9½
crosshead bolts (4), diameter, inches	3½
crank-pin bolts, (2), diameter, inches	5
Crosshead pins (2), diameter, inches	10½
length inches	10
slippers, ahead (2), total area, square inches	616
backing (2), total area, square inches	616
Crank shaft, number of sections	4
diameter, inches	19½
axial hole, inches	6
after bearing, length, inches	26
2d and 3d bearings from aft, length, inches	23

Crank shaft, other bearings (5), length, inches	20
maximum distance between bearings, inches	51
coupling flange, diameter, inches	38
thickness, inches	4¾
bolts (8), diameter, inches	4½
pins, diameter bearings, inches	20½
length bearings, inches	19
diameter in webs, inches	21½
axial hole, inches	6
webs, H.P. and L.P., thickness, inches	12
1st M.P. and 2d M.P., thickness, inches	14
metal around crank pin, thickness, inches	7¾
shaft, thickness, inches	9¾
Thrust shaft, diameter, inches	19
axial hole, diameter, inches	6
length between bearings, inches	98
length of bearings, inches	20
collars, number	14
diameter, inches	31
thickness, inches	2½
space between, inches	4
surface one shaft, square inches	6,597.36
Line shaft, diameter, inches	18¾
axial hole, inches	6
Propeller shaft, diameter, inches	19½
axial hole, inches	6
strut bearing, diameter, inches	21¾
length, feet	8
stern-tube bearing, diameter, inches	21¾
length, feet and inches	4–6
Reversing gear, steam cylinder, diameter, inches	20
thickness, inches	1½
hydraulic cylinder, diameter, inches	9
thickness, inches	1½
stroke, inches	30
piston rod, diameter, inches	4
Eccentrics, on shaft, diameter, inches	36
couplings, diameter, inches	56
thickness metal on shaft, inches	2½
couplings, inches	2½
width on shaft, inches	6
couplings, inches	6½
bolts in sheaves, diameter, inches	2½
strap bolts, diameter, inches	2½
Valve gear links (2), depth, inches	6½
thickness, inches	2½

Valve gear links (2), distance between, inches	8
centers and end bolts, inches	60
eccentric-rod pins, ins.	36
eccentric-rod pins, diameter, inches	3¾
length, inches	3⅝
suspension-rod pins, diameter, inches	2¾
length, inches	3
eccentric rods, diameter, upper end, inches	3½
lower end, inches	4¼
length center to center, inches	108
rod bolts, upper (4), diameter, inches	1¾
lower (2), diameter, inches	2½

MAIN BOILERS.

The main boilers are eight in number, six double and two single-ended. The single-ended and three double-ended are located in the after boiler compartment and the other double-ended in the next compartment forward; the fire rooms being all athwartships.

They are all of the horizontal, return, fire-tubular type, four furnaces in each end, with a separate combustion chamber for each furnace.

The boilers are designed to furnish steam at a working pressure of 200 pounds per square inch, and were tested to 300 pounds.

The shells of the double-ended consist of three courses and the single-ended of two courses, with three plates to the course.

The combustion chambers are secured to each other and to boiler shell by screw stays, the bottoms fitted with stiffening angles and the tops braced by double plate girders.

Doubling plates are fitted around lower manholes in wake of stays.

A Banca tin fusible plug is fitted to the top of each combustion chamber; the screw stays have a $\frac{1}{8}$-inch hole drilled in each end, extending $\frac{1}{2}$ inch beyond inner surface of sheets.

The principal riveting is as follows:

Longitudinal shell joints; double butt straps, $1\frac{1}{4}$ inches thick, treble chain riveting, alternate rivets in outer row omitted; diameter rivets, $1\frac{7}{16}$-inch. Circumferential shell joints, at mid-

dle, treble lap riveted, $1\frac{7}{16}$-inch rivets; at ends, double lap with $1\frac{1}{4}$-inch rivets.

Tube sheets to upper and lower heads; double lap, with $\frac{7}{8}$ rivets.

The furnaces are secured to combustion chambers by lap joints, double riveted, $\frac{7}{8}$-inch rivets.

DATA FOR ONE MAIN BOILER.

	Double-ended.	Single-ended.
Length, feet and inches	20–3	10–3½
Diameter, mean, feet	16	16
Thickness, shell, inches	1⅛	
head, top, inches	1 1/16	
bottom, inch	⅞	
tube sheets, inch	⅞	
furnaces, inch	⅞	
combustion chamber, side, inch	9/16	
back, inch	9/16	
bottom, inch	½	
back plating, inch	...	½
top head, inches	...	1 1/16
bottom stay plates, inch	½	
doubling strips, inch	½	
Main stays, in steam space, number	14	
diameter, inches	3⅜	
pitch	16 by 16	
Combustion-chamber screw stays, side, diam., in.	1¼	
pitch, in.	6 by 7	
back, diam., in.	1½	1½ and 1⅝
back, pitch, in.	6 by 7⅛	
top, diam. in.	1¼	
top, pitch, in.	6 by 7	
Total heating surface, all main boilers, sq. ft.	44,912	
grate surface, all main boilers, square ft.	1,072.1	
ratio H.S. to G.S., all main boilers, sq. ft.	41.8	
Furnaces, exterior diameter, inches	44½	
interior diameter, inches	40	
length grate, feet and inches	5–9	
area grate, square feet	153.16	76.58
Tubes, number	1,152	576
length between tube sheets, ft. and ins.	7–¾	
spaced vertically, stay, inches	7½	
horizontally, stay, inches	10½	
vertically, ordinary, inches	3½	
horizontally, ordinary, inches	3¾	

Tubes, thickness, ordinary, inch		.134	
stay, inch		$\frac{5}{16}$	
Net area through tubes, square feet	29		14.5
Lower main braces, number	7		14
diameter, inches		$2\frac{5}{8}$	
Heating surface, tube, square feet	5,320		2,660
furnace, square feet	396		198
combustion chamber, sq. ft	700		350
total, square feet	6,416		3,208
H.S. over G.A.		41.8	
G.A. over tube area		5.3	
Area through boiler tubes (one end), square feet		14.5	
Ratio to grate surface		5.287	
Area through heater tubes (one end), sq. ft		12.2	
Ratio to grate surface		6.27	
Heating surface in heater tubes (one end)	1,130.97		1,088.56
Ratio to boiler-tube heating surface	2.36		2.44
Area through ash pit, each furnace, square feet		9.82	
Ratio to grate surface		6.08	

AUXILIARY BOILER.

A vertical auxiliary boiler is located on the main deck, just forward of engine-room hatch.

Heating surface, tubes, square feet	470
fire-box, square feet	71
total, square feet	541
Grate surface, square feet	21
Area through tubes, square feet	3.6
Ratio, H.S. to G.A.	25.7
G.A. to tube area	5.8
Diameter of boiler, internal, feet	6
fire-box, feet and inches	5–2
Smoke Pipes, height above grates, feet	108
diameter inside, fore and aft, feet and inches	12–9
athwartship, feet and inches	9–3

Screw Propellers.—The propellers are three-bladed true screws, the starboard right, and the port left-handed.

The hub is of cast-steel, fitted to a taper on shaft. It is secured by a nut on end of shaft and a feather key fitted the length of hub; the nut is inclosed in a conical cover bolted to after face of hub.

The blades are of manganese-bronze secured to the hub by nine steel stud bolts with composition cap nuts.

The pitch of blades is made adjustable by means of oval bolt-holes in blades.

Number blades	3
Diameter, feet and inches	19-6
Pitch as set, feet	25
Diameter, hub, feet	5
Length, hub, feet and inches	3-11½
Projected area, 3 blades, square feet	73.3
Developed area, 3 blades, square feet	96.2

Main Air Pumps.—The main air pump for each engine is of the Blake vertical, cross-compound, double-acting type.

The pumps take their suction at the center of the length of pump cylinder and discharge through valves at the top and bottom; there are no suction or bucket valves; the plungers are composition castings, cored out for lightness; they are not fitted with packing or rings, but have a smooth face.

Steam cylinders, H. P., diameter, inches	12
L. P., diameter, inches	20
Pump cylinders, (2) diameter, inches	24
Stroke, inches	18
Depth of plunger, inches	16½

Main Circulating Pumps.—There are four main circulating pumps, two for each main condenser.

The pumps each have a capacity of 6,080 gallons of water per minute when pumping from the bilge; the two for a condenser are driven by a compound engine, one being connected to each end of the crank shaft.

The body of the pump is of cast-iron and the runner of composition.

Steam cylinders, H.P., diameter, inches	11
L.P., diameter, inches	20
Stroke, inches	10
Pump runner, diameter, inches	42
width at shaft, inches	8
periphery, inches	3
Inlet nozzle, diameter, inches	14
Outlet nozzle, diameter, inches	14

Main Condensers.—There is one main condenser in each engine room, abreast the main engine; the shells are of steel, water

heads of composition, and tube sheets of rolled brass; the tubes are supported along their length by two $\frac{3}{8}$-inch steel plates. Three baffle plates are fitted in steam space.

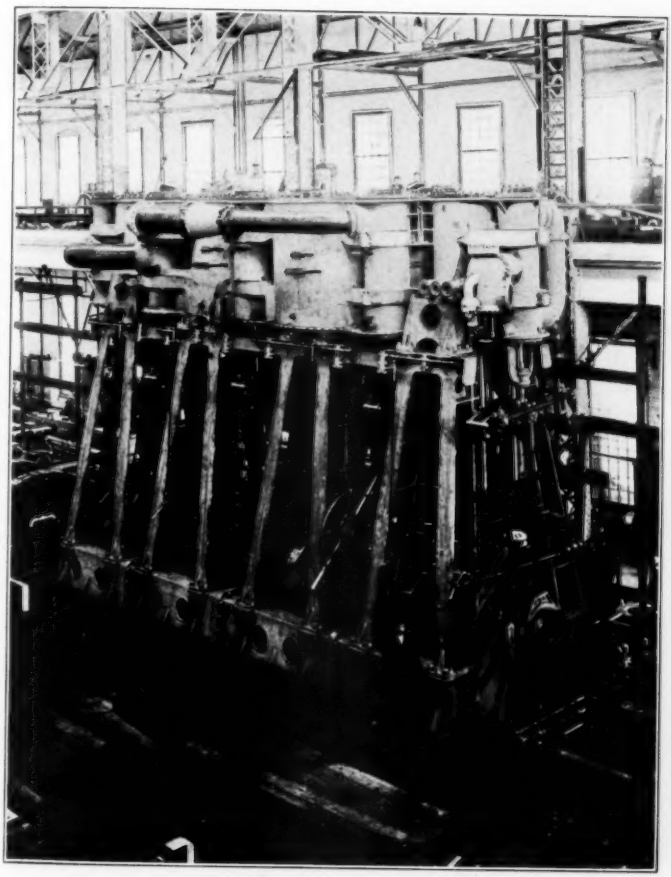
Circulating water enters at the bottom of condenser and passes through the tubes.

Number	2
Shell, inside diameter, feet and inches	7–2½
length between tube sheets, feet and inches	15–0
thickness, inch	⅜
Tubes, number, each condenser	4,003
diameter, outside, inch	¾
thickness, B. W. G.	18
pitch, inches	1⅛
Cooling surface, each condenser, square feet	11,787
total, square feet	23,574
Tube sheets, thickness, inch	1
Main exhaust nozzle, diameter, inches	24
Circulating water inlet (2), diameter, inches	14
outlet (1), diameter, inches	19
Ratio total cooling surface, main condenser, to total heating surface, main boilers	.525
Cooling surface per I.H.P., square feet	1.347

Auxiliary Condensers.—There is an auxiliary condenser with combined air and circulating pump in each engine room. They are used for condensing steam from auxiliaries, when not under way, and that from evaporators intended for make up feed.

Number	2
Shell, length, feet and inches	7–8½
diameter, inside, feet and inches	2–3
thickness, inch	¼
Tubes, length between tube sheets, feet and inches	7–10
diameter, inch	⅝
thickness, B. W. G.	18
Cooling surface (one), square feet	600
Pump, steam cylinder, diameter, inches	10
water cylinder, diameter, inches	12
air, cylinder, diameter, inches	12
stroke, inches	12

Main Feed Pumps.—There are two main feed pumps in each engine room; they are of the Blake simplex, vertical, piston type; steam cylinder, 16 inches; pump cylinder, 12⅝ inches and stroke, 18 inches.



ONE MAIN ENGINE OF THE "KOREA."

Donkey Boiler Feed Pump.—There is a Blake duplex, horizontal, piston pump, 4½ inches by 2 inches by 4 inches, in the port engine room, for feeding the donkey boiler.

Hot-Well Pumps.—There is in each engine room a Blake simplex, vertical, piston pump, which takes water from the filter tank and delivers to the feed-water heater; size, 8 by 12 by 18 inches.

Fire and Bilge Pumps.—One in each engine room; Blake duplex, horizontal, piston; size, 10 by 9 by 12 inches.

Ballast Pumps.—There is a Blake simplex, compound, vertical, piston, ballast pump in each engine room; size, 8 by 16 by 12 by 18 inches.

In the forward fire room there is a combined fire and ballast pump located in the upper grating; it is the Blake duplex, vertical, piston type; size, 10 by 8 by 12 inches.

Sanitary Pumps.—One in port engine room, a Blake duplex, compound, horizontal, piston pump; size, 8 by 12 by 12 by 12 inches. One in starboard engine room, a Blake duplex, horizontal piston pump; size, 8 by 7 by 12 inches.

Small steam pumps are fitted for pumping out the oil which is collected in crank and eccentric pits, and one in port engine room supplies the upper tanks of main-engine oil service.

Drainage System.—Main and auxiliary drain pipes are fitted in the double bottoms, and through them the pumps may be used for pumping various compartments.

Feed-Water Heaters.—There is located, at about the level of the main engine cylinders, in each engine room, a "Webster Vacuum Feed Water Heater and Purifier."

This heater is built upon the same principle as the jet condenser; the steam from the auxiliaries exhausts into it and is mixed with the feed water pumped in by the hot-well pump.

The hot-well pump is regulated by a float mechanism on feed tank, and the feed pump, which takes its suction from the heater bottom, is regulated by float mechanism connected to the heater, so that the amount of water pumped into the heater, and consequently the amount fed into the boilers, depends upon the height in the feed tank.

Forced Draft.—The closed fire room system is used, the air

being furnished by thirteen blowers located on main deck around uptakes. The blowers are driven by two-cylinder engines; diameter cylinders, 5 inches, stroke, 4 inches; diameter fan, 60 inches; width, 19 inches.

The air is heated by the escaping gases on the Howden system before entering the furnaces.

Ventilating Fans.—Air is supplied to cabins on upper deck by two Sturtevant blowers in engine-room hatch, each driven by a 5-H.P. electric motor.

Ice Machines.—There are two 8-ton ammonia refrigerating machines on the main deck abreast the engine-room hatch; they are of the type manufactured by the Vulcan Iron Works of San Francisco, in which compound engines are used.

Two Blake compound pumps, $4\frac{1}{2}$ by $6\frac{1}{2}$ by 6 by 7 inches, are used for circulating the brine through cold-storage rooms.

Evaporating Plant.—Two evaporators, manufactured by the Jas. Reilly Company of New York, arranged to work in double effect, are located in each engine room, with a distiller on each upper engine-room grating; the latter is used only for drinking water, which runs by gravity to the tanks. The make-up feed is condensed in the auxiliary condensers. The capacity of each of these evaporators is 25 tons of fresh water per day.

There is a salt-water feed and a fresh-water pump for each pair of evaporators; these are Blake simplex, vertical, piston type, 6 by 6 by 8 inches.

Electric Plant.—The electric plant consists of two 35-kilowatt generators of the General Electric Company's Marine type, situated on main deck in same compartment with the ice machines.

They are driven by compound tandem engines, cylinders, $7\frac{1}{2}$ and $12\frac{1}{2}$ inches with 6-inch stroke, and furnish current for about 850 sixteen-candlepower lights and two five-horsepower motors.

Each machine supplies 318 ampéres current at 110 volts, when running at 400 revolutions per minute.

DECK MACHINERY.

Anchor Windlass.—A steam windlass, built by the Hyde Windlass Company, of Bath, Me., is located on the forecastle; this is

the ordinary ship type, with wild cats for anchor chain; these may ride loose on shaft, being controlled by friction brakes, or they may be connected to shaft by pawls.

The engine is of the two-cylinder, vertical, inverted, direct-acting, reversible type; diameter of cylinders, 16 inches; stroke, 14 inches.

Capstans.—There are three capstans on the forecastle, which, through shafting and clutch couplings, may be driven by the anchor engines.

Two capstans on the poop are each driven by a two-cylinder, horizontal engine; diameter cylinders, 10 inches; stroke, 10 inches. The shaft of the port one extends into steering-engine room, where, by means of chains, it may be connected to the tiller and used for steering; the valve on engine being operated by levers in steering-engine room or on deck at the engine itself.

Deck Winches.—There are eight cargo winches on upper deck, four at each main cargo hatch; they are driven by two-cylinder, 8 by 8-inch engines.

A boat-hoisting winch, with a two-cylinder 6 by 6-inch engine, is located on deck house abaft forward smoke pipe.

Steering Gear.—The Brown patent steering gear, manufactured by the Hyde Windlass Company, is used. The engine has two cylinders; diameter, 7½ inches, and stroke, 12 inches. It is mounted upon the tiller, and operates a spur wheel which gears into a stationary circular rack, through an arc of about 90 degrees.

The after end of the tiller is secured to the rudder head direct, while forward it is supported on shoes which travel on the upper surface of circular rack. Springs are interposed to relieve strains on tiller.

Ordinarily the steering engine is controlled by a telemotor, arranged as follows: A cylinder is formed in the wheel standard in pilot house; a piston moving in this cylinder is operated by the wheel; the cylinder in pilot house is connected by piping to a cylinder in steering-engine room. In this latter is a piston which, through a system of levers, controls the valve of the steering engine. The system being filled with liquid, any motion of pilot-house piston is conveyed to the one in steering-en-

gine room. The position of steam valve is such that the motion of tiller tends to close and those of the telemotor to open it.

The pilot-house gear may be disconnected, and telemotor operated from steering-engine room.

The ship may be steered by means of the port after-deck capstan, either on poop or by levers in steering-engine room. Hand steering wheels are also fitted in steering-engine room.

Tell-tales for indicating helm angle are fitted on bridge, in pilot house, and in steering-engine room.

Mechanical Telegraphs.—These are of the Cory type and are installed as follows:

Engine room telegraph—from both sides of bridge to each engine room, with electric light attachment to indicate direction of motion of engines.

Docking telegraph—from bridge to forecastle and poop for use when coming alongside a dock.

Steering-engine telegraph—from bridge to steering-engine room.

Fire-room telegraph—from engine room to fire room.

Whistle and Siren.—These may be operated by hand gear on bridge or by an electric attachment which may also be connected to a clock for making fog signals.

TRIAL TRIP.

The *Korea* left the Company's wharf at 6·30 A. M., on March 20, 1902, and returned at 11·45 A. M., on the 21st.

The run was under natural draft except from about 2·30 to 5·00 P. M., on the 20th, when the blowers were started, links run out to full gear, and throttle opened wide.

As there was no measured course the speed by log only could be obtained; the reading by log on run from Thimble Light to Cape Henry was compared with chart distance on both trips, and the correction applied to log reading to get speed for the trial.

Revolutions, main engines, starboard	88
port	87.2
Speed, knots per hour	20
Total I.H.P. main engines, maximum	17,902.4
Forced-draft blowers (13), revolutions per minute, average	377

Air pressure in fire rooms, inches of water	1
Mean draught on trial, feet	27
Displacement, tons	18,400
Temperature in smoke pipes, degrees Fahrenheit	450

DOCK TRIALS.

The following data was obtained from dock trials, the engines running at full speed for one hour. The port engine was tried on March 5, and the starboard on March 7, the vessel being secured at the company's wharf:

	Star. Eng.	Port. Eng.
Boilers in use, double-ended	3	3
single-ended	...	1
Main steam, pounds per square inch	200	195
Steam at H.P. valve chest, pounds	193	195
Vacuum, inches of mercury	26	26.75
Steam, 1st receiver	93	81
2d receiver	44	37
3d receiver	1.5	5
1st M.P. jacket	62	85
2d M.P. jacket	26	42
L.P. jacket	18.5	19
Revolutions per minute, main engine	77	79
circulating pump	102	98
blowers (6)	...	392
air-pump, double strokes, H.P.	37	30
L.P.	30	23
Mean effective pressures, H.P. cylinder, top	74.64	91.20
bottom	70.56	95.88
1st M.P. cylinder, top	45.18	43.80
bottom	53.22	48.54
2d M.P. cylinder, top	18.93	17.04
bottom	18.30	17.91
L.P. cylinder, top	9.65	9.60
bottom	9.95	9.23
Aggregate M. E. P. referred to L.P. piston	39.6	40.5
I.H.P., H.P. cylinder, top	921.8	1,155.3
bottom	826.2	1,151.1
1st M.P. cylinder, top	1,138	1,132.5
bottom	1,307.8	1,222.8
2d M.P. cylinder, top	935.5	874.5
bottom	893	896.2
L.P. cylinder, top	970.1	990.4
bottom	996.5	949
total	7,988.9	8,371.8

TORPEDO-BOAT DESTROYERS.

By S. W. Barnaby.

[Paper read before the Institution of Naval Architects.]

So much attention has been drawn to the destroyer class of the British Navy during the past year, that no excuse is needed for a short paper on the subject.

It will necessarily be short, because no full treatment of the question is possible, in view of the fact that a Committee is now sitting at the Admiralty, and is investigating all the cases in which defects due to weakness of construction are reported to have developed during service at sea. I shall not therefore attempt to discuss these cases, because the facts have not been authoritatively made known. Neither do I wish to express an opinion as to the loss of the *Cobra*. I will only say that, although she was an exceptional and experimental vessel, still, if we are to believe that no injury to the bottom preceded the accident, it must be considered surprising that no preliminary straining or laboring of the joints gave warning of danger. We have no experience of mild steel, of the high quality to which we have become accustomed, having failed suddenly, even under repeated applications of stresses well within the elastic limit of the material; but as to what really happened, the evidence, to my mind, is not at all conclusive.

The problem which was originally set the destroyer builders was to produce a small vessel which would be faster than a torpedo boat, and would carry a heavier armament. These were the sole conditions imposed. Messrs. Yarrow and ourselves, who made the first designs, naturally worked on the lines of the torpedo boats which we had been building for years. Speaking for ourselves, we had confidence, from our experience with these boats, that if destroyers were developed on the same lines they would be at least as seaworthy as torpedo boats, if not more so.

We had built over 200, some of which had made voyages in all weathers and to all parts of the world, and not one had been lost at sea through insufficient strength. We considered that they must be amply strong to live through any weather in which they might be caught, but that the officers and men might reasonably be asked to submit to the same amount of discomfort at sea as was borne by the crews of torpedo boats, seeing that they were designed for the special purpose of catching these boats.

The torpedo gunboat of 800 or 1,000 tons is probably the smallest vessel in which any degree of comfort for the crew can be secured when it is necessary to remain constantly at sea; but although the torpedo gunboats may be able to overhaul torpedo boats in rough weather because of their size, a class was wanted which would overtake them in any weather, and I think this want has been met by the present destroyers. So far as I know, this condition of discomfort has been cheerfully accepted by the Navy, and the important question is, Can these small vessels of high speed be made reasonably safe at sea? I think there is no doubt that they can.

The strains coming upon a ship among waves are not exactly, or even approximately calculable. The effect of the inertia forces produced by the rapid motion of the ends of the vessel as she pitches and scends cannot be estimated, because the velocity of the motion of the parts is not determinable. It is not necessary to enumerate the complex forces produced by the motion in a seaway; it is sufficiently evident that the data for exact calculation are altogether wanting. Then, again, while at one moment the deck of the vessel forms the top of the girder, and the keel the bottom, at the next moment the rolling of the vessel may make the corner of the deck take the place of the top, and the opposite bilge that of the bottom of the girder.

All that it is possible to do is to establish a scale of comparison by which we may judge of the safety of one vessel by comparing her with another which has shown no sign of distress during the time that she has been at sea, and even then it is always possible that exceptional circumstances may occur which may cause us to modify from time to time our standard of comparison.

It is usual to suppose that by considering the vessel first as poised upon the summit of a wave of her own length, and then as lying between the crests of a pair of such waves, and reducing the hull to the form of an equivalent girder, that a method of comparing the stresses to which ships are subjected at sea is possible.

The vessel may never be in such a condition, probably never is, and if she were, the stresses would doubtless be different from what they are calculated to be; but in default of a better way of ascertaining if a given ship stands at least as good a chance of safety at sea as some other ship which has proved to be satisfactory, the test is a valuable one. It is usual to assume the height of the wave for vessels of this size as about one-twentieth of the length, and some idea of the severity of the supposed conditions may be obtained when it is stated that it means that a 210-foot destroyer is immersed to the gunwale at the two ends, and that only about 2¾ feet of the depth of the hull amidships is in the water when she is lying in the trough; and that when poised on the crest, about 34 feet of each extremity of the ship is out of the water altogether.

It is, of course, of great importance that the deck should not only be sufficiently strong to avoid buckling locally under compressive strains, but that the form of the deck, as a whole, should be rigidly maintained. In the long machinery compartments, where there are no bulkheads, either transverse or longitudinal, great care needs to be taken that the deck beams and longitudinal deck girders are sufficiently strong for the purpose. In some of the latest destroyers built abroad, where the engines are placed between the boilers, the coal-bunker bulkheads are continuous through the engine room, and greatly add to the strength amidships, but this arrangement obliges the engines to be placed one in front of the other, since there is not sufficient width for them to be abreast. This so greatly adds to the length of the ship, and consequently to the bending moment, that it is, to my mind, a doubtful advantage. The longitudinals and deep beams over these spaces will, no doubt, be reinforced in boats in which any tendency to bending has been observed. I think that

they might with advantage be further supported by pillars, in order to strengthen the deck to withstand the compression to which it is subjected under a sagging moment.

Our practice has been to make the deck perfectly straight for the greater part of the length of the ship, giving no sheer except at the bow. Any sheer amidships prevents the deck from taking its proper share of the tension coming upon the upper works under hogging moments, and throws undue stress upon the sheer-strake.

One of the most important factors determining the strength or weakness of a destroyer—more important, in my opinion, than the thickness of the plating—is the ratio of depth to length.

In the *Albatross*, which is the longest we have built, there are 15¼ depths in the length; but in some of the class, I believe, the depth is much less in proportion. Two destroyers may have the same scantlings of plates and frames, and be alike in length and displacement, and yet one may be a weak ship and the other a perfectly sound one; and especially may this be true if there is a great disproportion in relative depth.

As regards details, to which we attach great importance, I will only mention one or two. Unless the greatest care is taken in leveling the deck and shell plating by hand upon the slab, parts of the plate will be more severely strained than other parts, and the strength of the whole plate will thereby be reduced; but this is an operation requiring great skill and taking much time. No amount of machine rolling will level these plates as they require to be leveled, if the full advantage is to be taken of every pound of the material.

Joggling the butts of deck plating is, in my opinion, an undesirable practice, especially when this is of high-tensile steel. I think it not only injures the plates to treat them in this way, but it also prevents the full tensile strength of the plate from coming into play. A joggling stringer butt, for instance, is subjected to an unfair pull, which has to straighten the kink in the plate before it can stretch it, and an excessive strain is thrown on the sheer-strake.

The riveting is another detail requiring the greatest care, and

we never allow this to be done by piece-work. The introduction of high-tensile steel has made the question of riveting of still greater importance. The value of this material would be much enhanced if rivets of the same strength could be employed; but there are difficulties attending its use, and not much experience has been gained with hard steel rivets up to the present.

If rivets, either of mild or hard steel, are riveted cold, they appear to become brittle and treacherous, and our experience has satisfied us that good Lowmoor or charcoal-iron rivets are more reliable, and as strong as steel rivets when put in cold. Rivets of small diameter cannot, we believe, be safely put in hot, whether they are iron or steel, because they are liable to waste by scaling in heating, and are cooled so rapidly on being put into the holes that there is not time to properly knock them up before they arrive at a temperature at which hammering is injurious to steel. We therefore prefer iron rivets for sizes up to $\frac{3}{8}$ inch or $\frac{7}{16}$ inch, but those of $\frac{1}{2}$ inch or upwards might be of steel, and should be worked hot. It may be possible to use high-tensile steel for these, if it is certain that its quality is not affected by the heating, on which point more experiments are desirable. The spacing of these rivets could be greater than with iron rivets, and the plate would be stronger at the joint.

The ratio of weight of structural hull to total displacement in destroyers is not unduly light, and does not compare unfavorably with that found in other classes of warships. For example, Sir William White, in his "Manual of Naval Architecture," gives the weight of material contributing to structural strength in a steel-built first-class battleship of the present day as 18 per cent. of the total displacement, and for a typical swift protected cruiser of high speed, large coal supply and heavily armed, as 20½ per cent. of the total displacement. This is considerably less than the percentage of weight of material contributing to structural strength in torpedo boats and torpedo-boat destroyers.

Although the Thornycroft destroyers are not longer in proportion to depth than the earlier torpedo boats, we have taken more care to preserve the continuity of longitudinal strength

than was done in those boats. Continuous keelsons, side stringers and deck stringers have been introduced which were not fitted in the torpedo boats, and far more attention is now paid to the fitting of doubling plates in way of openings in the deck, such as funnels, fan cowls, hatchways, &c., in order to compensate for the material cut away by these openings, and thus to bring the strength there up to that of a normal section taken through the rivet holes at a frame, which should be the weakest section in the ship. To this question of compensation the Admiralty have very properly attached great importance in all their recent specifications, and there is no doubt that it is much more necessary to pay careful attention to it than it was in torpedo boats, on account of the increase in dimensions.

The longitudinal bending moments for similar ships on similar waves vary as the fourth power of the linear dimensions, so that the stress per square inch of material will increase with increase of dimensions if weight of hull vary as displacement, and as a rule this is found to be the case. Large ships are usually more highly stressed than small ones. M. Normand and others have shown that structural weights should vary as the four-thirds power of the displacement for equal stresses under longitudinal bending in similar vessels. But in dealing with moderate increases of dimensions, as in passing from a torpedo boat to a destroyer, there are a good many of the scantlings, such as plating over propellers, doublings and chafing plates in way of anchors, coal-bunker bulkheads and shoveling flats, and other parts which do not count for much in structural strength, but which require to be of a certain minimum thickness for local strength in the smaller vessel, and which do not need to be increased in the same proportion as the rest. The weight thus economized can be utilized in thickening the deck, keel, and sheer strake amidships above their proper proportion, and thus the stresses per square inch of material do not rise at the rate that they would otherwise do. As a matter of fact, we have found that by improvements in structural detail, such as I have mentioned, it has been possible to keep the estimated stresses in a seaway down to a figure which allows a good factor of safety,

taking into consideration the strength of the high-tensile steel employed.

There is no reason why boats having speeds of 30 or 31 knots at light draught should not be as capable of living through bad weather as a torpedo boat. This was the original standard; and, provided that they are equally well proportioned and equally well built, they should run no greater risks than their prototypes did. If a higher standard of strength than this is now considered desirable for destroyers for the British Navy, so that instead of working from a base they may always accompany the fleet at sea, I believe this requirement can be met without a great sacrifice of speed.

It would be unfortunate if the exaggerated impression which has got abroad as to the frailty of destroyers as a class should lead to a swing of the pendulum in the direction of increase of weight which should greatly exceed the necessities of the case. If we go to such heavy scantlings, or if we so increase the dimensions in order to secure comfort at sea, that destroyers can no longer be fast enough to overtake torpedo boats in smooth water, would not their usefulness be much impaired? Other nations will probably continue to build small fast craft of this description, in which comfort is sacrificed to speed and efficiency, and can we afford to be left behind?

The present destroyers, like the torpedo boats, are lightly built at the ends, and it is necessary to give special attention to the bow plating and framing in new boats, so that they may be able to maintain speed in rough water. Besides the local strengthening of the bows and a moderate increase of scantlings generally—say from 10 to 15 per cent.—to enable them to stand more knocking about, I think it would be wise to increase the ratio of depth to length even above that of the *Albatross*. The strength should then be ample for all requirements.

I do not feel at liberty to say anything about the latest designs that have been called for by the Admiralty, in which builders have been left, as usual, a fairly free hand. The moderate speed specified, 25½ knots, is due chiefly to the conditions of trial, which has now to be made with full load on board, and not, as pre-

viously, with a very light load. Although I should have preferred to see the trial made under average conditions of load—this is, in fully equipped condition, but with bunkers half full, rather than in either of the extremes of loading, still I can see no reason why thoroughly good boats should not be built under the new conditions laid down, provided that moderate views are allowed to prevail as to the hull weights and dimensions which are left to the judgment of the designer.

They will not be as fast at a light draught of water as the present boats are in that condition, but their speed will be increasing all the time as the coal burns out, and the average speed should be considerably more than that obtained on trial.

In view of recent events, what is a safe stress upon the material either of the deck in compression, or upon the keel in tension?

Do our views upon the subject require modification, and, if so, to what extent?

Fairbairn found, many years ago, that the joints of an iron-riveted girder sustained upwards of three million changes of one-fourth the weight that would break it without any apparent injury to its powers of ultimate resistance. It broke, however, with 313,000 additional changes when loaded with one-third the breaking weight, evidently showing, he says, that "the construction is not safe when tested with alternate changes of a load equivalent to one-third the weight that would break it." There are numbers of large ships at sea in which the stresses must be considered very high if judged by this standard, but which have shown no signs of distress. This would seem to indicate that the extreme conditions assumed in the stress calculations are very rarely met with, and that if they do occur, they last for a comparatively short time. But we have to remember that it is more difficult to get a thin plate to stand a compressive strain than a thick one, and also that small vessels are likely to encounter waves which will strain them more frequently than large ones. The waves which are assumed in stress calculations of battleships are given by Sir William White as 383 feet in length and 24 feet in height; while those assumed for a 210-foot destroyer are 10½ feet only. Of course, the destroyer which has

to keep company with a battleship may be called upon to encounter the 24-foot waves, but these, on account of their greater length, do not produce such a severe bending moment as the smaller wave. The boat cannot stretch from crest to crest, and is better supported than upon the shorter waves of less height. But, as I said before, these calculations cannot be depended upon for exact figures, and are only useful as methods of comparison.

I have my own opinion as to how high a stress it is safe to allow; but it would serve no useful purpose to attempt to fix a definite limit, where so much depends upon workmanship and other indeterminable quantities. The builder's own experience should be his guide. If all vessels had to be built to the rules of insurance societies, there might be less risk, but there would certainly be less progress; and torpedo boats and destroyers could never have come into existence.

Discussion.

Mr. A. F. Yarrow was the first speaker. He complimented the author on the interesting paper, which contained much valuable matter. To deal fully with the subject would mean a book rather than a speech, and he could, therefore, only touch on a few of the more salient features brought forward. The elasticity of the structure was one of the most important matters that had to be considered. Under blows from the sea the hull gave, otherwise it would soon be destroyed; but though elasticity was necessary it was desirable it should be uniform. If the movements set up were concentrated mainly in any one part, the metal there would get fatigued, and that would be a point of weakness. In making the calculations for strength they should consider an elastic body, and therefore an increase in section might localize a place of weakness; as an illustration he would imagine a clock spring. If a hole were bored through, it would be weakened at that place; but if the metal were thickened, it would also localize the position at which it would be likely to give way. In the case of the destroyer, buckling of the deck was one of the most im-

portant things that had to be taken into consideration, and here it was that the need for good workmanship was very apparent. If a plate were subject to tensile strength, it would not be affected if it were not quite flat; but if it were subject to compression, an initial weakness would be set up, and buckling would result.

Mr. Barnaby had illustrated a method of joining stringers, and had shown how a plate was joggled to make the joint, which he had indicated was a bad method. Mr. Yarrow agreed with this; in fact, he could not understand any shipbuilder making a joint of that kind by joggling; bending the plate in that way was to start a buckling effect. It was equivalent to making a nick in a bar that was subject to tension. His own practice was to make the joint by a double-butt strap. He was very glad Mr. Barnaby had drawn attention to the necessity to care in flattening plates; that was of the utmost importance, especially in thin plates, subject to compression, and needed very skilled labor to carry it out. In regard to the plating over the boilers, it was well known that the heat would be likely to expand the plates, and they would not, therefore, be in a good condition to stand a compressive stress; in fact, he thought the structure would be stronger if the plates were left out altogether. In regard to what had been said about the value of good workmanship, a very practical proof of this might be found in the rates at which underwriters were prepared to accept insurance risks for destroyers. They varied from 6s. 8d. as the lowest rate for some builders to two guineas. That was an indication of what very practical people thought on the value of good workmanship and attention to details. In conclusion, Mr. Yarrow said he was glad of the opportunity of expressing his firm conviction that torpedo-boat destroyers with the present scantlings are of ample strength to ensure the safety of those on board in any weather if skilfully handled, provided the workmanship was exceptionally good and that proper attention was given in the design to those details which are so essential in vessels of light construction. Any further material put into the structure of the hull would only tend to reduce the speed and usefulness of this class of vessel, without any corresponding advantage.

Mr. J. I. Thornycroft said the subject was rather a difficult one to discuss in view of the fact that it was being made the object of an inquiry, and he would not therefore go into the details of construction. Speaking generally, he would say, however, that it was of the greatest importance that builders should not be handicapped by restrictions and forced to build vessels that would not answer the purpose for which they were intended. He considered that more risk must be allowed in these vessels than in ordinary ships, and that it was useless to ask for more than a fair chance of safety. The vessels formed an admirable school for training of young officers, and it would be foolish to legislate so as to put them out of existence.

Admiral Sir N. Bowden Smith disclaimed any knowledge of building of destroyers, nor could he claim to have had experience in handling them, as they had come into use at a period when he had attained a rank beyond that at which such craft would fall to his lot. When, however, he was commanding at the Nore, he had come to the conclusion that destroyers were too frail. After a three-weeks' cruise they hardly ever came into port without damage to the hull. The slightest collision between them—the running against a buoy, or by rubbing against the wharf—and they would be damaged. Another reason for failure was the high power that was in them. In the old days when a ship met with a heavy gale she had to lie to because there was no help for it. Vessels had small power, and it was the only way they could battle against the elements. With the high power of the destroyers there was great temptation to subject the vessels to excessive strains. The *Cobra* was making for port when she foundered. If she had laid to, no damage would have occurred. He agreed that destroyers were perfectly seaworthy, and could make long voyages. He remembered on the South American Station some torpedo boats coming into Montevideo; they had sailed across the Atlantic with their propellers unshipped.

Dr. Elgar said that the author had treated the subject very judiciously. It seemed now to be accepted that destroyers had

failed in some way, but designers and builders never heard, after these vessels had left their yards, of structural weakness from the Admiralty, and it was only during the last few months that any hints of the kind had come to their ears. The boats were designed for special work, everything was sacrificed to speed, and it had not been asked that they could keep the sea in all weathers. Contractors would have hesitated to submit them for complete seagoing purposes. The speaker was surprised, indeed, that they came out as well as they did, and he doubted whether any one would have predicted their excellent performance from the calculations; but in these matters it was only possible to judge by experience. So far as he had heard, the defects of structural weakness were confined to the decks. He, like Mr. Yarrow, was surprised that the joggle joints should be used. Calculations showed, however, that it was not the top part of the boat that was weak structurally, but rather the bottom. The deck, however, was not supported against buckling. If greater weight of material was put in, it should be put into the bottom; but additional attention should be paid to strengthening the deck against buckling. With a high-tensile steel he would suggest that the riveting should be increased with advantage, and the double-butt strap would enable this to be carried out. In conclusion, he would say that it would be preferable to add to the strength by attention to details rather than by increasing the thickness of plating.

Mr. James Hamilton said that every ship was strong enough for some work, though it might be weak in certain conditions; ships were like engines or cranes—they should not be overloaded; what was necessary with all classes of vessels was to determine their safe conditions, and not to try them too high. In war, of course, risks would be run.

Admiral Sir E. Freemantle sympathized with Mr. Thornycroft and Mr. Yarrow in what they had said about the strength of the craft they had been so successful in producing. He thought destroyers had been overtried. It was not judicious to put a racehorse to drag a wagon, and that principle might be observed in

regard to torpedo-boat destroyers. He hoped the Admiralty would not insist on sacrificing everything to building destroyers which would be absolutely safe to keep the sea in all weathers, otherwise they would not have destroyers at all.

Admiral Morant said he would like to add his testimony. He had a son in the Service who was in command of a destroyer. She had to go to Halifax in a heavy gale, and was convoyed by the *Proserpine*. She had, however, made better weather than the larger craft. Another run had been made in very bad weather with the same result.

Admiral Henderson agreed with Admiral Freemantle that the limitations of the destroyer were not appreciated. He gave an instance in which a destroyer had to claw off a lee shore in a typhoon, which she did successfully. There was, however, a good deal of leakage at the bows through water coming in at the seams under the heavy blows of the seas.

In reply to the discussion, **Mr. Barnaby** said that he was gratified in obtaining the views of naval officers, which were all reassuring. The boats as now existing, if carefully built, would, he agreed with Mr. Yarrow, stand the stresses of weather that were to be met with. If they were not driven hard through the seas in bad weather, leakage would not occur. Dr. Elgar was right in saying that the bottom plating was more stressed than the deck, but the latter was less designed to stand compression. If boats were well built, they could do with a lower factor of safety. He referred to two torpedo boats, built by Messrs. Normand, which had made 31½ knots. If destroyers were to catch these craft, they must not be overweighted with too heavy a structure.

REVIEW OF WATER-TUBE BOILERS NOW USED FOR MARINE PURPOSES, WITH A COMPARATIVE REFERENCE TO THE ORDINARY CYLINDRICAL TYPE.

By Ernest N. Janson, Associate.

No question has of late been more prominently held before the engineering profession than that of the marine type of water-tube boilers; this, perhaps, more on account of the apparent failures of certain types than the real merits and advantages of the boiler in general. Nor have any notable inventions involving new principles of action been discovered, but experience of some years of continuous use has taught many and important lessons. It may, therefore, be of interest to review a few of the more prominent types, with special reference to their general designs and details of construction, as these in a water-tube boiler, more perhaps than in any other mechanical structure, will eventually determine its practicability and, to a very great extent, its adaptability for service. If a construction is bad in details, its length of life for service and usefulness is extremely limited, although primary results may be excellent. It is greatly due to this that the position of the water-tube boiler used for marine purposes at the present time is found unsatisfactory, with special reference to conditions presented in the English Navy, where some expensive lessons were brought to light on account of the unsuitability of the type chosen. The best obtainable water-tube boiler has probably not yet been produced, but nevertheless, it is reasonable to look upon those at hand as possessing sufficiently strong qualities to justify us in the assertion that, with some further improvements and modifications, its future may be considered positively assured.

One of the important questions confronting us when about to adopt a new device, and particularly on board ship, is the degree

of simplicity involved in its construction. The types of engines and the general classes of machinery now in use are so thoroughly tried, have such recognized merits and are of designs so well known and principles of manufacture so uniformly established that any thoughts of serious failures are in most cases quite remote. With a different knowledge and with a considerably lessened confidence, do we approach the question of the selection of any certain type of water-tube boiler. This may best be proven by the number of different types of boilers ordered to be installed in the very latest ships authorized to be built for the British Navy, occurring, as it does, at this advanced date, when necessity, from one cause or another, levies its demand for such boiler installations. This necessity is fully established in all the navies of the world, and, no doubt, will make itself felt more generally also with regard to ships for mercantile purposes. The determining factors as to the choice of a certain type will probably then, more than it has been up to the present time, be found under the heading of a perfect system worked out to meet a simple construction, with special attention paid to practical requirements as to detail parts, more and more subordinating such qualities as extreme lightness and an exceptional degree of efficiency.

WATER-TUBE *VERSUS* CYLINDRICAL BOILERS.

When compared with the cylindrical boiler the items of weight, space, steam pressure, economy and facilities for installation appear most notable. Regarding weight and space of water-tube boilers, in comparison with the ordinary cylindrical type, almost all of the former have a decided advantage, which may be approximately judged by the table on the opposite page, in which the figures represent data obtained from recent constructions.

The weights given are those of the boilers complete when in operation, but do not include uptakes. The space is represented by the projection of the boiler on the floor from the extreme contour in the rear to the furnace doors.

The pressure in a cylindrical boiler seems to be limited to about 210 pounds per square inch, although as high as 225 is

being used. In a water-tube boiler, it has a very wide margin, and can with safety be carried far beyond the pressures desirable for the present style of marine engines.

Name of boiler.	Weight per sq. ft. of heating surface.	Floor space—grate (actual space).	Steam pressure.	H. S. G. S.	Sectional or non-sectional.
Babcock & Wilcox	25–26	1.87	250	42	Sectional.
Niclausse	28–30	1.5	250	42	"
Belleville	38	1.61	250	31	"
Dürr	26.5, incl. sup. heater.	1.61	213	42	Semi-sectional.
Thornycroft	18* 12.5†	2.1	250	56	Non-sectional.
Normand	12.5†	2.2	210	47	"
Yarrow	12† 20‡	2	250	50 60	"
Cylindrical	73	2.12	210	33	"

* Monitor *Arkansas*, including air heaters. † Torpedo boats. ‡ Battleships (large tubes, 1¾ inches diameter).

The cylindrical boiler is generally credited with a higher degree of economy than the water-tube type, and is, in this particular, often getting more than its due credit. With equally favorable conditions in the circulation of the water and the gases of combustion in different types of boilers, the economy may be put down as a function of the average quantity of combustible burnt per square foot of heating surface, and economic results, therefore, under this assumption, should but slightly differ. Viewing the question in that light, the water-tube should be, at least, as economical as the fire-tube boiler. But as economic results also depend on the following circumstances, viz:

1. Degree of completeness of the combustion;
2. Condition of heating surface;
3. Temperature of flue gases;
4. Condition of casing, in which is involved:
   (a) Radiation, (b) Air leaks,

it will be interesting to note if any considerable amount of difference must prevail in the two types of boilers.

1. The combustion, if not generally so good in the water-tube boiler, could be largely improved by increasing its furnace capacity, or by more generally adopting some system of heated-air supply to the furnaces, by means of which the completeness of combustion is greatly enhanced and reduced uptake temperatures established, even with a diminished water heating surface. The value of air heaters in a steam plant for ship use was thoroughly demonstrated by the investigations made by the British Boiler Committee in comparative tests undertaken on the cruiser *Minerva*, and the Cunard steamer *Saxonia*. The thermal efficiency of the boiler plant of the latter ship, which was fitted with the Howden forced-draft system, reached the exceptional figure of 82.3 per cent., whilst in the former, even after retarders had been fitted in the tubes, averaged only about 68 per cent. The loss from incomplete combustion, whether in a water-tube, or in a Scotch boiler, working under similar conditions, may be considered nearly equal and average from 4 to 6 per cent. of the total heat expended.

2. The condition of the heating surface in a straight-tube water-tube boiler is more readily kept efficient than that of a cylindrical boiler, and any loss of efficiency from this source will therefore be less.

3. The temperatures of the uptake gases are kept as low in a properly baffled water-tube boiler as in the cylindrical type, the loss in heat, which on an average is about 20 per cent., will consequently quite equalize in the two types.

4. The condition of the casing is, apparently, in favor of the cylindrical type of boiler, as the heat loss from this source and with this type averages only about 2 per cent. of the total heat transmitted to the steam, while it may be as high as 5 per cent. in the water-tube type. In addition to this, the influence of air-leaks in the casing of a water-tube boiler must be carefully considered, as they may be of such magnitude as to entirely undo any attempt at a fair comparison. As the latter two conditions are dependent almost wholly on design and workmanship, the defects may, in most cases, be avoided and the consequent losses eliminated. We may then, on the ground above taken, consider that the average efficiency of a well-designed and well-built water-

tube boiler need be no less, could be and is made as high as that of the cylindrical type.

In support of the contention cited above, it will be interesting to cite a short extract from a note by Messrs. Thomas Wilson, Sons and Company, of Hull, England, to the "Pall Mall Gazette" of November 6, 1900. The firm above mentioned is extensively using water-tube boilers (principally the Babcock & Wilcox). They write as follows:

"Sir: We notice a paragraph in your issue of the 6th instant, referring to our S. S. *Martello*, in which you stated that this vessel burnt 448 tons more coal on her voyage (7,000 miles) since fitted with water-tube boilers, than she did previously with ordinary cylindrical boilers.

"This is quite incorrect; the coal consumption with water-tube boilers on her first voyage being 100 tons less than the average of three years with ordinary boilers, and the speed is 1.72 knots faster. It is also to be noted that the boilers weighed 115 tons less than the old boilers, which were four in number.

(Signed) THOMAS WILSON, SONS AND COMPANY."

For the purpose of either removing old boilers or making installations of new ones, the sectional water-tube boiler has a very great advantage over the cylindrical boiler. This refers particularly to warships with heavy protective decks and small hatch openings. Those types of water-tube boilers which are not sectional in form, have, of course, only a partial advantage in this respect over the cylindrical type, and that is in the feasibility of erecting them in the ship, but their eventual removal will cause considerable trouble.

COMPARISON OF VARIOUS TYPES OF WATER-TUBE BOILERS.

The following desiderata may be considered of importance when comparing the various types, and in trying to establish a basis for design and construction.

1. The desirability of having the boiler so constructed, that its manufacture may be executed by any well-equipped boiler shop, and its repairs such as can be done by persons not specially skilled.

This would greatly augment its more general adoption.

2. Parts should be of a simple and uniform construction with as few of the parts different to one another as possible, all to be of such shape and size as to allow easy examination, with ease in repairs or renewals, and of a thoroughly reliable material. This would reduce the number of spares necessary, and aid the personnel in becoming readily familiar with the boiler; also minimize liability to accidents.

3. It should be made sectional or in repetition of certain elements, and of large units with reference to the steam collectors, but of small furnace units.

This would simplify steam connections and reduce the number of pipe fittings. It facilitates firing and renders the installation of the boiler easier.

4. The parts constituting heating surface should be so disposed, relatively one to another, that a maximum of heating surface is obtained within a minimum space, and the floor space occupied be such that it closely approaches that of the grate area.

This insures a large ratio of power to unit of area of floor space occupied.

5. The circulation of the steam and water must be as direct as possible, and the generating tubes so arranged that the circulation easily becomes accelerated with higher degrees of combustion.

This insures a protected condition of the tubes with reference to oxidation or overheating, and in that way adds to the safety and life of the boiler.

6. Any part should be self-sustaining, making all surface staying unneccessary.

This will diminish the liability of accidents.

7. Baffles, preferably provided by the special disposition of the generating tubes, should be so arranged that a perfect system for complete combustion of the gases is produced as well as insuring their conduction over the whole of the heating surface. They should, however, not add materially to the resistance of the flow.

This increases efficiency, renders a high degree of forcing possible, and reduces uptake temperatures.

8. The component parts to be independent of one another to such degree that no disturbance is caused to other fixed parts by their removal and repairs.

This minimizes expense and time necessary for the upkeep of the boiler.

9. It must have provisions for taking up any derangement or distortion in the shape of tubes or other parts due to expansion or contraction when in operation.

This prevents leaks and loss of feed water.

That quite a number of the water-tube boilers possess such of the essential qualities as make their use indispensable is best proven by their almost unlimited employment in almost every branch of the naval service of every country. A short review of the boilers so used may enable a better comparison in regard to their relative employment and purpose.

Belleville.—The history of this boiler covers a period of many years, and was introduced as early as fifteen years ago in the French Navy, and was some seven or eight years ago taken up as the standard boiler by the British Admiralty. At about the same time it was introduced in the Northern Steamship Company's two new steamers, *North Land* and *North West*, of Buffalo, of about 7,000 I.H.P. each; the boilers for these two ships are, however, now being removed after some eight years of unsatisfactory service, and are not to succeed themselves. The principal reason of their failure in these vessels, as well as in the majority of other instances, is the destruction of the tubes due to inherent defects and the serious difficulties in the way of keeping the plant in satisfactory working conditions. Although the careful product of years of trial and experiment, this boiler must be looked upon as one of great complexity in design and details, and cannot, on account of the attention necessary, be operated successfully in any large installation. It is also necessary to have the aid of such men as have had much experience with this particular boiler. Owing to the frictional resistance in the generating coils and with an inclination of coil of but

a few degrees, and varying in total length from 90 to 120 feet, with numerous bends, the circulation, as a matter of course, must become more inferior, causing the formation of steam plugs, deposits and overheating, with eventual bursting of the tubes. Its appurtenances for the regulation of the feed, the purifying of the water and the separation of moisture existing in the steam, together with various other contrivances, renders the apparatus, as a whole, quite unreliable. With thin and carefully-kept fires, using, for instance, nothing but anthracite coal, which is not apt to clinker, and thus insuring an even heat all over the boiler, it is said to give no trouble with the tubes, and can be regulated with a remarkable precision in its steam production. If, however, for any cause, for instance, slicing, the fires should become uneven and very hot in spots, places in the tubes become at once overheated, with subsequent trouble.

Due to want of simplicity and to inherent faults in the design itself, it is not suitable for use on board ship to the same extent as other types. This statement will, no doubt, by some be regarded as inconsistent, in view of the apparent success the boiler has attained in actual service, such as, for instance, in the French Messageries Maritimes, which company has had a long and satisfactory experience with this boiler. These ships, however, contain comparatively small boiler installations, and are therefore much easier supervised and controlled than those in a warship, with its numerous boilers in the several compartments, with a duplication of auxiliaries. In the English Navy is at present installed, or under way, more than twice as much Belleville-boiler power as the next largest (France), and its experience must accordingly be entitled to the fullest consideration.

Niclausse.—This boiler, although its time of trial in actual service has neither been as varied nor as extensive as that of the Belleville, has, on the whole, established for itself a satisfactory record. Notwithstanding its manufacture must be of a most accurate nature, the boiler when finished cannot be called complicated. Its greatest constructive advantage lies in the facility and ease with which any individual tube may be taken out and again inserted. When properly put in place, tightness is assured,

owing to the small stress actually brought on the joint, due to the almost complete balance of the tube itself. A feature of disadvantage is the inability to thoroughly drain the boiler except by special appliances, such as syphoning or emptying each tube separately. The nature of the cone joint between the tubes and the headers causes the observer, at first glance, a certain amount of distrust, and is sure to leave him with more or less prejudice. The actual trials seem, however, to show this joint to be quite reliable, and to resist leakage as long as due care is taken in keeping up its original perfection. Similar joints are used with equally good results on the Dürr and Montupet boilers, no trouble, in fact, being experienced so much from that end of the tube as from the free end. Due to the abrupt turn of the water when circulating from the inside to the outside tube, it seems as if the circulation would become materially impeded, and in case of excessive forcing, overheating of the tubes ensues with subsequent bending and distortion of the part outside the header, or in other words, the free end. Judging, however, from such trials as that of the Russian cruiser *Variag*, built by Cramps, in Philadelphia, and the French torpedo boat *Temeraire*, the circulation is such as to warrant even an unusual amount of forcing. In the trial of the *Temeraire* it is claimed 84 pounds of coal were burnt per square foot of grate during ten consecutive hours, under the supervision of French officers, with satisfactory results.

Means for baffling the gases have, as far as known, not yet been devised, and for that reason the economic results, especially when forced, cannot be the best.

The necessity of removing the inside tubes for the purpose of cleaning the generating tubes of scale or deposits, materially adds to the arduousness of this imperative duty and detracts from the constructive advantages. On account of the small space occupied by this boiler and its perfect accessibility for all purposes, it is specially well adapted for installation on ship board.

Babcock and Wilcox.—No boiler is better known than this, despite the fact that only a few years have passed since it was introduced on an extensive scale for maritime purposes. It may without hesitation be said that this boiler is representative of

simplicity in design, and as now manufactured, of an advanced degree of workmanship. With its expanded tube joints, great strength, reliability and tightness, is obtained. It must be conceded, however, that with this system more time and work is required to remove and renew any damaged parts. The furnace being made up of water elements enclosing the sides, becomes more durable than in either of the types already mentioned, although not quite so efficient, which, however, is fully made up for by a very complete system of bafflers among the tubes. The arrangement of the tube system being an assurance of a good water circulation, a considerable degree of forcing may, in case of necessity, be resorted to without injurious effects. Forcing with its consequent high temperature of the gases, is also made practicable by the method adopted for baffling these gases. Due to the arrangement of flame plates or bafflers, it is necessary to clean the boiler from the side, requiring additional room in the form of passageways, and, therefore adding to the area of floor space necessary. The size and shape of the headers makes this boiler a specialty of manufacture, and in this respect it resembles the Niclausse boiler. As all tube doors are comparatively large and flat, except in cases where plugs are used, it is necessary to secure the best of packing to prevent leakage, especially when a sudden drop of pressure occurs. The feed of these boilers requires no refinement or special appliances, even as simple an arrangement as that of a feed pump connected to the main engine being of quite sufficient utility.

This boiler is largely used in the merchant service and is being installed in quite a number of United States warships as well as in foreign services.

Dürr.—The most striking point of similarity between this boiler and the Niclausse is the concentric tube arrangement. The difference otherwise, however, is sufficiently distinct to separate each as an individual type. First of all, the Niclausse boiler is sectional in all of its parts, while the Dürr boiler is so only with regard to the tubes, which all have their connections made to an unbroken water front built up of flanges and stayed steel plates. The Niclausse tube has two firm, conical supports

in the header, each separated by a distance of from 7 to 9 inches, thus giving a firm hold for the tube. The cone joint in the Dürr, on the contrary, consists of a single attachment to the rear sheet of the water front, in which it is accurately fitted. It is therefore of great importance to have the diaphragm plate holding up the rear end of the tubes of such construction that practically no warping or distortion is possible, as this would no doubt tend to cause some derangement of the tube itself. These tubes are not held in place by any separate mechanical device, but by the unbalanced pressure due to its back end being closed. This pressure will amount to several thousand pounds in a large tube with a boiler pressure of over 200 pounds. The tubes, which are generally arranged so as to have an incline of about 8 degrees from the horizontal, cannot be thoroughly drained except by a special operation applied to each tube separately, and with reference to cleaning the inside of the tubes almost the same trouble is met with as in all boilers containing the concentric tube system. It is not as much of a specialty construction as is found in some of the types already mentioned, and is probably cheaper in first cost. It has gained considerable favor within the last few years in the German Navy and is being extensively tried by other nations for further introduction.

Yarrow.—This boiler, like those previously mentioned, has the advantage of containing straight generating tubes, but, unlike the others, is non-sectional. As hitherto built, the tubes are of a small diameter, ranging from one inch to one and one-quarter outside. The practical superiority of larger-size tubes for boilers intended for vessels of a heavier type than torpedo boats is generally acknowledged, both on account of the possibility of increasing their gauge without seriously lessening their internal area, as well as the increased facilities for examination, together with considerably-diminished effects from corrosive actions. This fact has been taken advantage of in recommending this type of boiler for battleships and armored cruisers in the latest designs made up for the British Navy, to such an extent that tubes of a less diameter than one and three-quarter inches must not be used, which, in many respects, will add to the serviceability of

this boiler. The greatest defect of the boiler in question, however, is the rigidity of the tube arrangement, allowing for only a small amount of flexibility under conditions of unequal expansion or contraction, which invariably causes the tubes to bend, although not seriously. Retubing or repairs to any interior tubes meet with difficulties and necessitate the removal of the other tubes, unless the pitch is such that a tube could be slipped between two adjoining tubes, or the upper or lower drums made in halves. The general arrangement provides for a comparatively large furnace, and the amount of combustible that can be burnt is therefore large, but, owing to the lack of an efficient system of baffling, the loss from the escape of very hot unburnt uptake gases must be considerable. This is, however, partly offset by the adopted system of using heated air in the furnace. This air, being taken through the casing surrounding the boiler before it enters the furnace, increases the efficiency of the combustion. This boiler occupies a large floor space, compared to its grate, but is quite accessible for examination and cleaning, and its simplicity of construction and low cost in manufacture add to its merits.

Thornycroft.—In the original *Speedy* type of boiler all the generating tubes terminated above the water level. This has the decided advantage of creating a positive circulation, as the water cannot reenter the tubes except from below. The greatest part of the length of the tubes being almost vertical insures a very good circulation, increasing in intensity with the amount of forcing. The tubes, being bent into various shapes, make the construction quite flexible, but render the cleaning of the internal surfaces most difficult, or an examination of the tubes in general next to impossible. This tends to limit the life of the boiler. The inside of the furnace and the outside of the boiler are formed into continuous tube walls by special bending of the tubes, and for the purpose of directing the gases over the heating surface have a decided advantage over any kind of mechanically arranged baffle plates. After deflecting from the top of the furnace the gases enter the triangular spaces between the tubes near the bottom drums, rise vertically along the whole length of the boiler

at the same time, and escape through similar spaces either at the top or at the bottom of the upper drum, depending upon whether it is a single or double-furnace boiler, like the *Daring* type. It has separate downcomers outside of the casing, and with the large bottom drums, as are now generally used, the floor space occupied is considerably in excess over that required by some of the boilers already referred to. It is true that a boiler of this type may be highly forced, and in this way, dimensions kept down, but this is not only uneconomical, but also tends to shorten the life of the boiler. In order to minimize the effects from oxidation in the curved part of the tubes, extending above the upper drum, a form of this boiler is also made with a number of the tubes terminating under the water level; this in order to give room and such shape to the remainder of the tubes that no air pockets could form in any part of them.

Normand.—Unlike the arrangement in the Thornycroft boiler, the generating tubes in this boiler terminate below the water line in the steam drum, and instead of the gases rising vertically, they traverse the boiler horizontally. In order to accomplish this, the tubes, forming the fire walls in the furnace, are tangent one to another for the whole length, except at the end opposite the uptake, where they are bent out for the inlet of the gases, and are similarly arranged on the extreme outer row near the casing; the openings between the tubes always being at opposite ends of the boiler. The same disadvantage with reference to space occupied, examination and cleaning of the tubes, exists in this boiler as in all the boilers containing small-diameter bent tubes. The easiest way to overcome the trouble from a damaged tube is to plug it top and bottom, an extraordinary amount of work being required to renew such a tube in an arrangement where the inner rows are obstructed by each succeeding outer row. Due to the perfect system of baffling, this boiler may be forced to a higher degree than almost any other, and due to this, it is being used with great success in torpedo-boat service.

Schultz—Thornycroft and Schultz.—At first glance, there is apparently a great resemblance between this boiler and the Thornycroft, in fact, so much so that the two types have been

consolidated under the name Schultz-Thornycroft boiler. The Schultz-Thornycroft having the general tube arrangement of the Thornycroft with similar water circulation, but with a circulation of the gases conforming to that of the Schultz type. The Schultz boiler consists of a large steam drum with at least three, and often more, smaller water drums. From these latter drums issue groups of tubes, containing equal numbers of small-diameter tubes, which all terminate above the water line in the upper drum. When first made, it had, like the Thornycroft or Normand, large downcomer pipes on the outside, but in later designs these are dispensed with, and downcomer tubes of the same diameter as the generating tubes are placed within the boiler proper, either at the end or middle of a group of generating tubes. In order to cause these downcomer tubes to be unaffected by the action of the hot gases, they are enclosed within a sort of casing built up of generating tubes. These tubes, like the tubes forming the flue walls, have the ends reduced where entering the drums, with the centers so arranged that the enlarged parts come close together. The baffling of the gases in this boiler is made most complete by an arrangement of the flue walls, composed of tubes in which the enlarged parts meet, and the gases enter between the openings left by the contracted parts. In this way, the gases may enter at one end of the furnace into one group of tubes and there circulate the whole length of the boiler, first to the front and then, due to a dividing flue wall, back again before the uptake is reached. The claim of reduction of space occupied by this boiler on account of the outside downcomers having been done away with, holds good, but the corresponding reduction of heating surface must be taken into consideration; the real advantage being more in the direction of giving greater flexibility to the structure as a whole, by taking away such large and very stiff pipe connections between top and bottom drums. Although the efficiency of the boiler by the complete system of baffling may be somewhat increased, it is certain that the facilities for its proper care and upkeep are diminished in an equal ratio. It is used to a great extent, in conjunction with cylindrical boilers, in ships of the

German Navy, and will, no doubt, prove successful under such conditions. If, however, the boiler plant was entirely made up of the Schultz type of boiler, and by necessity, all the boilers should have to be used continuously for any length of time, the efficiency of the plant would perhaps rapidly fall below requirements and seriously impair the efficiency of the ship.

Guyot-DuTemple.—The DuTemple boilers, which usually are given the credit of being the pioneers of the small-diameter bent-tube boiler, had originally from three to four almost horizontal bends in each cluster of tubes, which were then less than three-quarters of an inch in diameter. Owing to inferior circulation with this system, it was subsequently changed to the present Guyot-DuTemple boiler. In its essential features it is quite like the Normand boiler, except that the curvature of the tubes more nearly approaches that of a circle, and they are generally made with a special nut and cone fitting where the tubes join the drums, rendering them more easily removable. The gases circulate almost in the same manner as in the Normand. The Guyot-DuTemple boiler has in later years been introduced on a large scale in the French Navy, in ships of very large size, among which may be mentioned the armored cruiser *Jeanne d'Arc.* As far as is known, the trial of this ship was not successful, and this mainly on account of the failure of her boilers, of which there were twenty-four of large size. The maximum power—28,500 I.H.P., for a speed of 23 knots—was not to be secured by heavy forcing, as is ordinarily the condition with the small-diameter bent-tube type of boiler, the grate surface provided being large enough to not require a combustion of more than about 35 pounds of coal per square foot of grate. But, instead of the high ratio of heating to grate surface usual in this class of boilers, even at the rate of combustion mentioned, the ratio of heating to grate surface was kept considerably below that commonly observed as good practice, and was in fact no higher than in the large-tube boilers, in which two-thirds of the amount of coal above mentioned may perhaps be considered a high figure. Owing to the unusual space necessary for the boilers themselves, the fire rooms became too cramped for even ordinary working conditions. This, in

conjunction with an intense radiation of heat from the boilers, caused the overheating of the fire rooms, in which the temperature rose to 155 degrees Fahrenheit. The demoralization resulting under such circumstances is easily imagined. Twenty out of the twenty-four boilers were so badly burnt that repairs are said to be impossible. Occurrences like this point out very strongly the absolute necessity of providing most carefully-constructed casings, as well as the necessity of using such types of boilers as will admit of adequate space for their proper handling and for the reasonable comfort of the men operating them, without calling for an exhorbitant allotment of space for their installation. The necessity of a liberal heating surface in comparison with the grate is shown to be of the greatest importance in boilers intended for excessive forcing.

Lagrafel d'Allest.—One of the oldest types and forms of water-tube boilers is the Lagrafel d'Allest, which, in general construction, quite resembles the Heine boiler, which is largely used for stationary purposes. The tubes, which are straight, are expanded in the inner sheets of the front and back water walls, have an inclination of about 10 degrees to the horizontal, with the steam drums invariably parallel to the tubes. In the circulation of the gases, it differs from other straight-tube boilers, in that the gases travel across the tubes from side to side in their passage to the uptakes. When the boilers are placed in pairs, the bafflers are so arranged that the gases meet in a common combustion chamber, then, dividing, take the course as above described. The economic results obtained with an arrangement of this kind should be quite favorable; but as proven by experience with return tubular or cylindrical boilers, the greatest heat, striking the upper portions of the combustion chamber renders the liveliest circulation through the topmost rows of tubes. These upper tubes, however, in a water-tube boiler may, due to an accidentally low water level or on account of a more violent circulation in the lower tubes nearest to the furnace heat, be deprived of an amount of water necessary to withstand the heat of the gases, and in that way sustain severe damage, which with this

boiler has been the cause of some serious accidents. It is quite simple in general design as well as in details, but not as suitable for very high pressures as other types on account of the necessary surface staying. Its rigidity of construction, which prohibits its being heavily forced, is one of its disadvantages.

Blechynden.—The general design of this boiler bears quite a resemblance to the Yarrow boiler, but apparently possesses some strikingly good features not pronounced in the other. The slightly curved tubes give more flexibility to the structure, at the same time enabling the removal of these tubes through the holes provided for that purpose in the upper drum. In order to do this, however, considerable clear space above the boiler is necessary. It has two rows of tubes removed from the generating tubes, serving as separate downcomers, at the same time affording protection to the casing. This boiler is used to a large extent for torpedo boats in the Italian Navy.

Mosher.—The Mosher torpedo-boat type of boiler, consisting, as it does, of two entirely separate and distinct boilers enclosing one furnace, and with a steam connection uniting each boiler with the other in a co-acting system, possesses the advantage of extreme lightness in weight with a large amount of heating surface. Owing to this peculiarity of design (the duplication of the steam-drums), it is necessary to have separate steam and water fittings on each drum, which causes a duplication of appurtenances with necessary increased attention. The difficulty of maintaining the same height of water level in the two drums is detrimental to this design.

The boiler as proposed for the monitor *Florida*, contains several features like the Yarrow and Blechynden.

Other Water-Tube Boilers.—Although quite efficient, light and a rapid steam raiser, giving dry steam, the Ward type of boiler as installed in the U. S. *Monterey* was not repeated for other and newer ships. This was principally due to the inaccessibility of the tubes for repair and renewal in case of damage. The union joints, by means of which the tubes were attached to the headers, after having been in the fire could not be removed, and, with the adopted arrangement of tubes, cutting out of several tubes had

to be done before the damaged tube could be reached. The uptake temperatures were also excessive, due to want of baffling.

The *Towne* boiler, with its inclined cross-tube arrangement, offers, in its construction, a boiler of great compactness with a good circulation; its structural rigidity, however, unsuits it for forcing. On the whole, in its present form, it is only suitable for smaller installations.

The *Reed* boiler differs from the general type of the bent-tube boiler, principally in the attachment of the tubes and their shapes. This attachment consists of a semi-spherical fitting screwed on the end of the tube and seating into a corresponding socket in the shell, the whole being set up tight by means of nuts on the water side of the drums. This device has been found quite satisfactory, and greatly facilitates necessary repairs with regard to re-tubing, etc. The *Reed*, as well as the *White* boilers, are used on a large scale in torpedo boats and smaller cruisers in the British Navy.

The *Laird* boiler, as made by Laird Brothers, in Birkenhead, is the same as the Normand with a few of the details modified.

Modifications of the Thornycroft and Normand are the *Fore River* boilers, as used in the U. S. torpedo boats, *Lawrence* and *MacDonough*, and one type of *Seabury*, as used in the *Stewart*. Other types of water-tube boilers largely used for tugs, yachts and smaller vessels in the United States, are the so-called pipe-boilers, of which the *Almy*, *Roberts* and *Boyer* are well known. These boilers are composed almost entirely of ordinary tubes, pipe fittings, or specially-forged tube connections. Some of them are made sectional to such an extent that individual elements may be removed without injury to the other parts. Most of the joints between the individual parts being screw-joints, exposed to the fire or hot gases, entail great difficulties in renewing individual parts.

In order to more fully show to what extent water-tube boilers are now being used in the navies of the world, the following lists are appended, part of the contents of which were published in the August number of the JOURNAL of 1898. In connection with this list, it may also be mentioned, that the water tube is

now invariably installed for new naval ships to almost the entire exclusion of the ordinary cylindrical boiler, except in a few cases where part of the boiler power is yet obtained by using the latter type. That there is a tendency to gradually fall back entirely on water-tube boilers for naval purposes is best shown by the practice, for instance, in the Germany Navy, to utilize this type of boiler to an always increasing percentage. The Germans, who are conservative and very cautious in most of their undertakings, started out with a combination of water-tube and cylindrical boilers, the former to an extent of about 35 per cent. in the earlier ships, while now there is a percentage of some 70 per cent. in the two latest battleships, and water-tube boilers throughout for the last contemplated armored cruisers.

The quantities given represent the maximum estimated indicated horsepower as actually installed or in contemplation up to a recent date, but must only be considered approximately correct.

UNITED STATES.

Battleships, Cruisers, Monitors and Gunboats.	I.H.P.
Babcock & Wilcox boiler,	237,000
Niclausse boiler,	102,400
Thornycroft boiler,	34,400
Yarrow boiler,	800
Ward boiler,	2,500
Mosher boiler,	2,400
Torpedo Vessels.	
Thornycroft boiler,	142,500
Normand boiler,	33,400
Seabury boiler,	16,600
Fore River boiler,	16,800
Mosher boiler,	19,650

GREAT BRITAIN.

Battleships, Armored and Protected Cruisers.	I.H.P.
Belleville boiler,	904,900
Niclausse boiler,	28,300
Babcock & Wilcox boiler,	33,800

Smaller Cruisers, Gunboats and Torpedo Vessels.

Thornycroft boiler,	241,810
DuTemple boiler,	3,500
Yarrow boiler,	151,410
Normand boiler,	159,000
Babcock & Wilcox boiler,	6,300
Blechynden boiler,	33,900
Reed boiler,	126,900
White boiler,	35,200
Mumford boiler,	3,500
Laird boiler,	27,250

FRANCE.

Battleships, Armored and Protected Cruisers.	I.H.P.
Belleville boiler,	329,568
Niclausse boiler,	174,100
Lagrafel d'Allest boiler,	180,800
DuTemple boiler,	49,800
Normand boiler,	76,600

Smaller Cruisers, Gunboats and Torpedo Vessels.

Belleville boiler,	51,332
Niclausse boiler,	18,000
Lagrafel d'Allest boiler,	63,300
Normand boiler,	167,800
Thornycroft boiler,	10,000
DuTemple boiler,	11,700
Oriolle boiler,	7,100

GERMANY.

Battleships, Armored and Protected Cruisers.	I.H.P.
Schultz or Thornycroft-Schultz boiler,	142,750
Belleville boiler,	20,000
Dü boiler,	140,000
N isse boiler,	19,000
Thor croft boiler,	13,000

AUSTRIA-HUNGARY.

Battleships and Cruisers.	I.H.P.
Belleville boiler,	53,000
Yarrow boiler,	12,300

Gunboats and Torpedo Vessels.

Dürr boiler,	9,500
Yarrow boiler,	29,900
Thornycroft boiler,	8,300

CHILI.

Battleships.	I.H.P.
Bellevelle, boiler,	25,500
Torpedo Vessels.	
Normand boiler,	64,500

RUSSIA.

Battleships, Armored and Protected Cruisers.	I.H.P.
Belleville boiler,	335,500
Niclausse boiler,	67,525
Normand boiler,	76,000
Schultz boiler,	19,500
Smaller Cruisers and Torpedo Vessels.	
Yarrow boiler,	42,500
Belleville boiler,	10,000
Niclausse boiler,	2,640

JAPAN.

Battleships and Cruisers.	I.H.P.
Belleville boiler,	136,900
Torpedo Vessels.	
Thornycroft boiler,	6,000

HOLLAND.

Cruisers.	I.H.P.
Yarrow boilers,	91,400

ITALY.

Battleships and Cruisers.	I.H.P.
Belleville boilers,	48,600
Niclausse boilers,	46,000
Torpedo Vessels.	
Blechynden boilers,	43,500
Thornycroft boilers,	24,000

SWEDEN AND NORWAY.

Small Armored Cruisers.	I.H.P.
Yarrow boilers,	38,600
Torpedo Vessels.	
Thornycroft boilers,	12,100

SPAIN.

Battleships and Armored Cruisers.	I.H.P.
Belleville boilers,	6,500
Niclausse boilers,	21,500
Torpedo Vessels.	
Normand boilers,	14,500

ARGENTINA.

Cruisers.	I.H.P.
Belleville,	13,000

IN CONCLUSION.

Like different types of engines designed and built for different purposes of service, so also was each type of water-tube boiler designed and built to meet a special purpose.

The small diameter bent-tube boiler is considerably lighter in weight so long as it is intended for service in torpedo boats, because the tubes on the whole are made much lighter, and can well afford to be, on account of the more limited service expected from this class of boats. The heating service is also provided in more liberal proportions owing to a possibly excessive amount of forcing; this, however, cannot be had without occupying additional space. This extra space is easily provided for in the class of boats mentioned, due to the usual arrangement of the boilers, they never being placed side by side. Should this class of boilers be chosen for large ships, their weights at once increase on account of heavier tubes and larger drums required, and become almost as high as any type of large-tube boilers. Still more space will be necessary, as excessive forcing, shortening the life of the boiler and causing most uneconomical results, cannot be permitted. This latter has been clearly demon-

strated in the numerous coal-consumption trials of the English *Pelorus* class of cruisers. In addition to the disabilities already mentioned, arising as soon as this type of boilers is made to fit the conditions to be observed when used in large installations, the question of cleaning the boilers becomes of great importance. Every two or three days some of the boilers require to be laid up for this purpose, with attending inconveniences in the cruising routine.

The boiler suited for continuous working, with provisions for keeping it in an efficient state and with the least liability of being thrown out of commission on account of the failure of some of its more or less important appurtenances, is the type to be first considered, and these requirements can, apparently, better be met in types containing comparatively large and straight tubes. The matter of first cost should always be considered in connection with other important points, such as life of boiler, repairs likely to be required and the economic results while in actual service, but if any one boiler possesses a decided advantage over another in these latter points it should be adopted without regard to its possibly extra cost.

TORSIONAL VIBRATIONS OF SHAFTS.*

By Herr L. Gümbel.

The resolution, by the aid of Fourier's Theorem, of periodic into harmonic forces has already enabled us to solve a number of very important technical problems, such as the balancing of marine engines, the researches concerning the way in which the tangential forces of the engine can be rendered uniform, the problem of the pitching and rolling motion of ships, &c.

The paper I have the honor to lay before you to-day will demonstrate again how Fourier's Theorem helps us to open up a field which, as yet, has scarcely been accessible—namely, the study of the torsional vibrations of shafts.

Historical.—So far as I am aware, Dr. Bauer, of Stettin,† was the first to point out that there are torsional vibrations in the shafts of marine engines owing to the periodic fluctuations, both in the tangential forces acting on the cranks and in the propeller resistances. Dr. Bauer was led to this conclusion by actually measuring the angular velocities of shafts.

Professor Lorenz, of Göttingen,‡ has dealt with the matter mathematically. He does not take the propeller resistance into consideration, however, and hence does not deal with the actual conditions of the problem.

To Frahm, of Hamburg,§ we owe a very extensive contribution to this problem, by experiments conducted with admirable care and great ingenuity. We may look forward with particular interest to the detailed account of these.

In your country, I see in "Engineering," January, 1902, that Messrs. Julius Frith and E. H. Lamb have, in a paper read before the Manchester Section of the Institution of Electrical

* Paper read before the Institution of Naval Architects.

† "Jahrbuch der Schiffbautechnischen Gesellschaft," Vol. I, 1900.

‡ "Dynamik der Kurbelgetriebe," Leipzig, 1901.

§ "Verhandlungen der Gesellschaft deutscher Naturforscher und Aerzte," Hamburg, 1901.

Engineers, drawn attention to the fact that vibrations may arise, especially in the shafts of dynamos. I do not know how far their work has extended.

System.—In order to attack the problem, we may imagine the system comprising engine, shaft and propeller to be reduced to the following elements:

1. A mass m acting on the crank radius r at the middle of the crankshaft.

2. A mass M acting on the crank radius r at the middle of the propeller boss.

The masses m and M have to be such that mr^2 and Mr^2 represent the moments of inertia of the rotating masses of the engine and of the propeller respectively.

3. The two masses m and M are supposed to be connected by a shaft without mass, of uniform diameter and of lenthg L, measured from the middle of the crankshaft to the middle of the propeller boss. The shaft being assumed to be without mass, the angle of distortion of the shaft will be the same for all points of the shaft.

Composition of Masses.—The mass m will be composed of

(*a*) One-third of the mass of the shaft, reduced to the crank radius, and reckoned from the mass center of the system up to the end of the shaft on the crank side.

Proof.—Let ξ be the angle of torsion of a shaft section, at distance x from the center of gravity. Since the center of gravity remains at rest, when the shaft is in natural vibration, ξ will increase proportionately with x, so that $\xi = Cx$. Let $m_1 L$ be the mass of the shaft, and χ_m the angle measuring the distortion of the shaft at the crank end due to the mass acceleration of the shaft. Then

$$d\chi = C_1 m_1 \, dx \, \omega^2 r \xi x$$

$$\chi_m = C_1 C m_1 \omega^2 r \int_0^{L_m} x^2 \, dx$$

$$\left(\text{Where } L_m \text{ stands for } \frac{L.M}{M+m}\right)$$

$$= \frac{C_1 C}{3} m_1 \omega^2 r L_m^3.$$

The same value would result if we had only one mass $m_2 L_m$ on the shaft's end defined by the equations—

$$C_1 . m_2 . L_m . \omega^2 r . C . L_m . L_m = \frac{C_1 . C}{3} \cdot m_1 \omega^2 r L_m^3.$$

$$m_2 L_m = \frac{m_1}{3} \cdot L_m.$$

This substitution is strictly correct, of course, only for the natural vibrations of the shaft. The above term $\frac{L . M}{M + m} = L_m$ is the distance of the center of gravity from the assumed end of the shaft on the crank side, the corresponding distance from the boss being $\frac{L . m}{M + m}$. (Fig. 1.)

(*b*) The mass of the crank and crankpin reduced to the crank radius.

(*c*) The rotating part of the mass of the connecting rod $= \frac{m_c e_1 e_2}{l^2}$, where m_c is the mass of the connecting rod, l its length, e_1 the distance of the mass center of the rod from the crosshead, e_2 the distance between the center of the crosshead pin and the center of the rod.

(*d*) A certain part of the reciprocating masses—

$$= \frac{2}{\pi} \cdot \left(m_c . \frac{(l - e_1)}{l} + m_p \right)$$

where m_p is the sum of the masses of crosshead, piston rod, and piston.

The mass M is composed of:

(*a*) One-third of the mass of the shaft, reduced to the crank radius and measured from the center of gravity of the system to the propeller end of the shaft.

(*b*) The mass of the propeller and the boss, reduced to the crank radius.

Forces Acting on the System.—On the system as sketched out, the following forces are acting:

1. On the crank side acting on the crank radius:

(*a*) The tangential forces resulting from the steam pressure on the piston.

(*b*) The acceleration forces of the reciprocating parts under the supposition of a constant mean angular velocity.

The tangential force (*a*) due to the steam pressure is composed of a constant mean force and of periodic forces. The mass acceleration components (*b*) being likewise periodic variables, we have means at hand to equalize the non-uniformity of the tangential steam force by the mass acceleration, and this method of restoring uniformity is, indeed, in general practical use. As Professor Lorenz* has, however, asserted that the method could not be recommended, because the balance would be disturbed by any alteration of the engine speed, I should like to point out here that in marine engines, the tangential forces of the steam pressure follow practically the same law as the mass accelerations. Both are, with close approximation, proportional to the square of the number of revolutions. A change in the speed will therefore not affect the balance between the two forces.

2. On the propeller side acting on the crank radius:

(*a*) A constant mean resistance corresponding to a constant angular velocity of the propeller.

(*b*) Periodically variable forces of resistance corresponding to the variable angular velocity of the propeller.

3. There will be distributed over the whole length of the shaft damping forces, due to the internal friction in the shaft under torsion, and proportional to the angle of distortion and to the velocity of distortion. These forces can be resolved into a couple of equal and opposite forces, acting on the crank radius at the two ends of the shaft.

4. Further, there are acting at the two ends of the shaft the accelerating forces of the revolving masses m and M, whose intensity will depend upon—

(*a*) The angle α or β, respectively, of the end sections.

(*b*) The frequency of the vibrations.

The amplitudes of the forces will be $m\omega^2 r\alpha$ and $M\omega^2 r\beta$, respectively.

*Transactions, Institution of Naval Architects, 1900.

Fig. 3 represents this system of forces for a definite period.

Analysis.—Whatever may be the law governing the tangential force of the engine, we can always, by the aid of Fourier's Theorem, resolve this force into a constant mean force P, and into harmonic forces whose frequency will be a multiple of the number of the revolutions made by the engine, thus:

$$P = P_m + P_1 \cos(c_1 + x) + P_2 \cos 2(c_2 + x) + P_3 \cos 3(c_3 + x) + P_4 \cos 4(c_4 + x) \ldots,$$

where P_1, P_2, P_3 . . . represent the amplitudes of the harmonic forces, and the angles c_1, c_2, c_3 . . . the phases of the harmonic forces at the moment $x = 0$.

As regards the determination of the values of the P and c, I would refer you to Perry's excellent "Calculus for Engineers."

The mean force P_m being constant, there will be a constant angular velocity of the propeller, and a constant angle of torsion of the shaft. On the other hand, periodically variable propeller speeds and distortions of the shaft will result from the periodic forces.

The forces R which are due to this varying angular velocity of the propeller may likewise be expressed in a Fourier series of the form—

$$R = R_m + R_1 \cos(k_1 + x) + R_2 \cos 2(k_2 + x) + R_3 \cos 3(k_3 + x) + R_4 \cos 4(k_4 + x) + \ldots$$

In this expression may also be included forces occasioned by external circumstances, such as shocks, the passing of the propeller by the hull of the ship, &c., provided they recur at regular periods.

Conditions of Equilibrium.—The conditions of equilibrium between the forces of the engine and of the propeller demand that forces of equal frequency should be equal to one another—namely,

$$P_m = R_m$$
$$P_1 \cos(c_1 + x) = R_1 \cos(k_1 + x),$$
$$P_2 \cos 2(c_2 + x) = R_2 \cos 2(k_2 + x), \text{ &c.}$$

Law of the Propeller Resistance.—If we disregard any special external influences, and assume the propeller to be revolving in open water, the variable resistance opposed to the propeller will depend exclusively upon its angular velocity.

Fig. 2 is based upon Rota's experiments* concerning the magnitude of the propeller thrust T for constant ship speeds and variable propeller revolutions. Rota's law may be expressed by the equation—

$$T = -T_m + C(v_x - 0.3\,v_m)^2.$$

The propeller speed v_m corresponds to the condition of equilibrium. For this value v_m, the propeller thrust is equal to the ship's resistance: $Tm = C \cdot 0.7^2\, v_m^2$. When the propeller speed increases (or decreases), the ship's speed remaining constant—which is approximately our case—the propeller thrust will increase (or diminish) in accordance with the equation—

$$\triangle T = \frac{2T_m \triangle v_m}{0.7\,v_m}.$$

As long as the increase or decrease in v_m does not constitute any considerable part of v_m—as in the case in our problem—the increase in the thrust may be regarded as directly proportional to the increase in the propeller speed. Assuming a proportionality between the propeller thrust and the turning moment of the propeller, we may likewise consider the amplitudes of the periodic propeller resistance as proportional to the amplitudes of the periodic fluctuations in the propeller speed.

If, therefore, $\omega r \beta$ be the amplitude of the propeller speed, the amplitude of the propeller resistance will be $k \omega r \beta$.

Solution of the Problem.—To maintain equilibrium in the system, as indicated above, the geometric resultant of all the forces of the same frequency must become zero, since all the forces vary harmonically. This condition cannot be fulfilled without our knowing the phases of the component forces for any particular moment.

Let us once more, by aid of Fig. 4, review the component

* Rota, "La Vasca per l'Esperienze di Architettura Navale," Genova, 1898.

forces from this point of view. At the propeller end of the shaft there are acting on the crank radius r—

(1) The accelerating force $M\omega^2 r\beta$;

(2) The propeller resistance $k\omega r\beta$, which will attain its maximum at the moment of maximum speed; this vibration lags therefore by 90 degrees behind the variable $M\omega^2 r\beta$;

(3) The damping force $k_1 \omega r \frac{\alpha \sin\varphi + \beta}{\sin\varepsilon}$. The maximum of this component coincides with the maximum speed of deformation, and it will therefore lag by 90 degrees behind the deformation itself.

At the engine end of the shaft there are acting on the crank radius r—

(1) The accelerating force $m\omega^2 r\alpha$.

(2) The tangential force P.

(3) The damping force $k_1 \omega r \frac{\alpha \sin\varphi + \beta}{\sin\varepsilon}$. This component will be equal to the corresponding force acting at the propeller end of the shaft, but of opposite direction. The forces acting at the propeller end must at any moment be in equilibrium with the internal torsional forces in the shaft. The same holds good for the forces in play at the engine end of the shaft. It follows, then, that the resultant of the forces at the one end must be equal in magnitude, but of opposite sign, to the resultant at the other end. We thus arrive at the force polygon, of which Fig. 4 gives a diagram; it explains the relations existing between the different components.

Composition of the Vibration out of Three Partial Vibrations.— The vibrations of the terminals α and β are not pure torsional vibrations, but are composed of three partial vibrations.

(a) A torsional vibration, whose amplitude is indicated by the angle η or ζ respectively.

(b) A vibration of amplitude γ, which is the same for all the points of the shaft.

(c) A vibration at 90 degrees in advance of the torsional vibration, of amplitude λ or ν respectively.

The sub-division of the vibrations α and β into these compon-

ents is arbitrary, and the magnitude of the components can be varied by changing the phases the angles η and γ, and ζ and γ respectively interfere.

The sum of the torsional angles $\eta + \zeta$ is, of course, not variable.

Two ways of dividing α and β deserve particular attention.

(a) There is a phase difference of 90 degrees between η and γ, and ζ and γ respectively. In this case the resolution will yield the minimum value for the vibration γ in which all the points of the shaft partake equally.

(b) This vibration γ, which is common to all the points of the shaft, is supposed to be 90 degrees in advance of the propeller vibration β. This is the resolution adopted in our calculations for reasons presently to be explained. I wish to emphasize once more that any other resolution might be applied, and that the values of α and β, and of $\eta + \zeta$ are not influenced by the particular choice made. From Fig. 4 the following equations may at once be deduced:

(1) $$\gamma = \frac{k}{M \cdot \omega} \cdot \beta.$$

(2) $$\cot \varepsilon = \frac{k}{M\omega}.$$

(3) $$\tan \varphi = \frac{1}{\cot \varepsilon} \cdot \left(1 - \frac{C}{\sin \varepsilon \cdot \omega \cdot \sqrt{k^2 + M^2\omega^2}}\right).$$

(4) $$\beta\omega\sqrt{k^2 + M^2\omega^2} \cdot \sin \varepsilon = C\omega(\alpha \sin \varphi + \beta).$$

(5) $$\alpha = \gamma \cdot \frac{\sin \varepsilon}{\sin(\varepsilon - \varphi)}.$$

(6) $$\sin \delta = \frac{k\omega r\beta - m\omega^2 r\alpha \cdot \cos \varphi}{P}.$$

(7) $$\frac{P \cos \delta + m\omega^2 r\alpha \sin \varphi}{M\omega^2 r} = \beta.$$

The co-efficient C expresses the ratio of the torsional force acting upon the shaft to the angle of torsion.

$$C = \frac{I \cdot G}{L \cdot r^2}, \tag{8}$$

where I is the polar moment of inertia of a shaft section, G the modulus of elasticity, and L the length of the shaft.

From the equations (1) to (8) it follows that

$$\eta = \frac{\alpha \cdot \sin \varphi}{\sin \varepsilon} \cdot \cos \mu. \tag{9}$$

$$\zeta = \frac{\beta}{\sin \varepsilon} \cdot \cos \mu \tag{10}$$

$$\text{where } \mu = \frac{k_1 \cdot \omega}{C}. \tag{11}$$

For any given value of ω, the equations (1) to (11) can be solved for a given system of masses and forces.

Vibration of Any Point of the Shaft.—The amplitude and phase of the vibration of a point of the shaft in the distance x from the mass m will be found as the resultant of the following vibrations:

(1) A vibration of the amplitude $\frac{L \cdot \eta - x(\eta + \zeta)}{L}$ of the same or opposite phase of η.

(2) A vibration of the amplitude and phase of γ.

(3) A vibration of the amplitude $\frac{L \cdot \lambda - x(\lambda + v)}{L}$ of the same or opposite phase of λ.

Example.—The internal damping forces have not been taken into consideration in the following calculations, as the value k_1 seems indeed to be rather small in comparison to the value k of the resistance of propeller.

Hence $\cos \mu = 1$, and Fig. 4 alters to Fig. 5.

With the aid of formulæ (1) to (10), we can calculate all vibration values for a given force of any periodicity, having given the masses m and M, and the shaft dimensions when the propeller resistance k is known. Figs. 8, 9, 10 illustrate the results of such calculations for the following data:

$$m = \frac{10670}{9.81}\,\frac{kg}{m}\ \text{sec}^2.$$

$$M = \frac{27860}{9.81}\,\frac{kg}{m}\ \text{sec}^2.$$

$$r = 61\ cm.$$

$$L = 5248\ cm.$$

$$I = 103000\ cm^4.$$

$$G = 850000\,\frac{kg}{cm^2}.$$

Fig. 9 gives the values of the coefficient of the propeller resistance k, and Fig. 8 the periodic force P for frequencies of from 150 to 290 periods per minute, the frequency of P having been assumed to be four times the number of revolutions of the engine.

Fig. 8 reproduces the force polygons for different frequencies; the same figure marks the forces $M\omega^2 r\beta$, $m\omega^2 r\alpha$, and $k\omega r\beta$. Both the intensities and the phase differences of these forces change with the number of periods. Force and torsional vibration will be in the same phase for the speed 0 and forces 0; they will be in opposite phase, when the speed becomes $= \infty$.

Special Case $\delta = -90$ *Degrees.*—The frequency for which the angle δ becomes -90 degrees is of especial interest. In this case we have (compare Fig. 6),

$$\frac{m\omega^2 r\gamma}{M\omega^2 r\gamma} = \frac{m\omega^2 r\beta \sin\varepsilon}{\sin\varepsilon \,.\, Cr(\alpha\sin\varphi + \beta)},$$

and, therefore, as

$$m\omega^2 r\alpha \sin\varphi = M\omega^2 r\beta.$$

$$Cr(m+M) = m\,.\,M\,.\,\omega^2 r,$$

$$\omega = \sqrt{\frac{C(M+m)}{Mm}},$$

$$C = \frac{I\,.\,G}{L\,.\,r^2},$$

$$\omega = \sqrt{\frac{I\,.\,G\,(M+m)}{Lr^2 Mm}}.$$

Natural Vibrations.—If we imagine the whole system to be in free natural vibration, without any opposing resistance, the center of gravity of the whole system must remain unaffected by the vibrations of the component parts. Hence we may assume the shaft to be clamped at its center of gravity. We then have two systems—namely, a mass m vibrating at the one end at the distance $\frac{L \cdot M}{M+m}$ from the center of gravity, and a mass M at the other end at the distance $\frac{L \cdot m}{M+m}$ from the center of gravity.

From $m\,\omega^2 r\,a = C_a r\,a$, and $M\omega^2 r\,\beta = C\beta r\,\beta$, and, further,

$$C_a = \frac{I \cdot G}{L \cdot \frac{M}{M+m} r^2} \text{ and } C\beta = \frac{I \cdot G}{L \cdot \frac{m}{M+m} r^2}$$

results in both cases

$$\omega = \sqrt{\frac{I \cdot G \cdot (M+m)}{L r^2 M m}}.$$

This ω represents the angular velocity of the natural vibration of the system.

We see that this value of ω, corresponding to the natural vibration, is the same as that for which $\delta = -90$ degrees.

Important Formulæ.—The vibration plotted in Fig. 6 is therefore composed of the following partial vibrations:

(1) A vibration of amplitude γ in which all the elements of the shaft participate; the accelerating forces of this component are, at any moment, in equilibrium both with the damping force $k\,\omega\,r\,\beta$, and with the force P.

(2) A vibration exactly like free vibration of the shaft, unimpeded by any resistance. Whilst, however, the amplitude of a free vibration is indefinite, in the absence of any resistance, the damped vibrations in our case have a definite amplitude, which, as Fig. 6 indicates, will be for the propeller end

$$\beta = \frac{PM}{m\,k\,\omega\,r},$$

and for the engine end of the shaft

$$\alpha = \frac{\sqrt{k^2 + M^2\omega^2}}{m\omega} \cdot \beta = \frac{P.M.\sqrt{k^2 + M^2\omega^2}}{m^2\omega^2 r k}.$$

The angle of torsion of the two end sections of the shaft will be

$$\eta + \xi = \frac{P.(M+m)\sqrt{k^2 + M^2\omega^2}}{k\omega^2 r m^2}.$$

These formulæ are of very great practical importance.

The resolution of the vibrations α and β, which we performed above, into a torsional vibration η and ζ, and a vibration γ of all the shaft elements at right angles to β, has been made with special regard to this case.

We recognize in Fig. 10 that the maximum amplitude of vibration does not quite coincide with the natural vibration period of the shaft. This coincidence, in fact, occurs already at a slightly lower number of vibrations. In practice, however, the above formulæ will be found sufficient for the calculation of the critical values of α, β, and $(\eta + \zeta)$.

Forced Vibrations without Damping.—Those general formulæ further enable us to deduce special formulæ for the vibrations which, in the absence of damping, would result under the influence of the harmonic force P. In that case k will be 0.

We see from equations (2) and (3)—

$$\varepsilon = \varphi = 0 \text{ degrees},$$

and from equation (4)—

$$\beta . M\omega^2 r = C . r(\alpha + \beta),$$

and from equation (7)—

$$\beta . M\omega^2 r = P + m\omega^2 r\alpha,$$

and that, (1) the sum of all the external forces is zero; (2) the external forces are in equilibrium with the internal forces. $M\omega^2 r\beta$ and $m\omega^2 r\alpha$ vibrate in opposite phases.

As long as the number of periods is less than the natural frequency, P will vibrate in phase with $m\omega^2 r\alpha$; when the natural frequency is exceeded, P will pass over to the contrary phase.

We further deduce from those two equations—

$$\beta = \zeta = \frac{P \cdot C}{(M+m) \cdot C \cdot \omega^2 r - M m \omega^4 r}$$

$$\alpha = \eta = \frac{P(M\omega^2 - C)}{(M+m) \cdot C \cdot \omega^2 r - M m \omega^4 r}$$

The values of α and β have been calculated for the masses stated above, and the results have been marked on Fig. 10.

Both β and α become $= \infty$, when

$$(M+m) \cdot C\omega^2 - M m \omega^4 = 0,$$

that is, when—

$$\omega = \sqrt{\frac{C(M+m)}{Mm}}$$

i. e., for the number of periods corresponding to the natural vibration of the shaft.

The angle δ alters suddenly from 0 degrees to 180 degrees by passing the frequency of natural vibrations (Fig. 9).

Vibration of the Mass Center.—Some further interesting conclusions concerning the vibration of the mass center of the system may be derived from the polygon of forces of Fig. 5. The vibration of the center of gravity is the result of the composition of the torsional vibration $\frac{M\zeta - m\eta}{M+m}$, and of the vibration common to all the points of the shaft, γ.

If we trace in the polygon of forces (Fig. 5) the respective acceleration forces $(M\omega^2 r\zeta - m\omega^2 r\eta)$ and $(M+m)\omega^2 r\gamma$, we recognize that the resultant of these forces is equal and opposite to the resultant of the external forces P and $k\omega r\beta$, and we further find the rule confirmed that, whatever the internal forces of a system, the mass center will always move as if all the external forces distributed over the system were acting at that center.

Solution of an Example if a Periodic Force is Given.—Having exemplified how the amplitudes of the vibrations can be calculated for a given force of any periodicity, we will now follow the course of the amplitudes during one period for a definite speed, the shaft being acted upon by any given periodic force.

Fig. 11 shows the resulting tangential force diagram of an engine which is developed in the Fourier series—

$$P = 34760 + 1400\cos(240 + x) + 7000\cos 2(10 + x) + 3400\cos 3(20 + x) + 2410\cos 4x \quad (P \text{ in kg.}).$$

The engine speed is $n = 70$ revolutions per minute. Assuming that 90 per cent. only of the mean force, 34,760 kilograms are taken up by the propeller, the coefficient of the propeller resistance will be—

$$k = \frac{2 \cdot 0.9 \cdot 34760 \cdot 30}{0.7 \cdot 70 \cdot 3.14 \cdot 61} = 200.$$

We will further suppose that the periodic forces are reduced by 5 per cent. before they enter into action at the crank radius, and that they are thus expressed by the series—

$$1330\cos(240 + x) + 6650\cos 2(10 + x) + 3230\cos 3(20 + x) + 2290\cos 4x.$$

The amplitudes of the vibrations can be determined in the manner already explained, and we thus obtain the Table given below.

The polygons of the forces and of the amplitudes $\eta + \xi$, α, β, are reproduced in Fig. 7.

When we plot the vibrations of the separate periods in a rectangular system of co-ordinates, we find the resulting vibration by algebraical computation of the component amplitudes of that moment. Since we know the phase difference between each partial vibration and the respective force, we can also express the periodic vibration laws algebraically in a Fourier series.

AMPLITUDES OF VIBRATIONS.

Number of periods.	Simple.	Twofold.	Threefold.	Fourfold.
P. in kg.	1330	6650	3230	2290
β	0.00946	0.01993	0.01550	0.00204
α	0.00696	0.0149	0.03375	0.00949
$\eta + \zeta$	0.00445	0.0301	0.0460	0.01145
	deg. min.	*deg. min.*	*deg. min.*	*deg. min.*
ε	46 12	64 23	72 43	76 32
φ	−63 41	29 2	64 40	73 40
δ	33 40	14 53	−8 41	−159 42

We find—

$$\beta = 0.00946 \cos (93 \text{ deg. } 40 \text{ min.} + x) + 0.01993 \cos 2 (107 \text{ deg. } 26 \text{ min.} + x) + 0.0155 \cos 3 (77 \text{ deg. } 6 \text{ min.} + x) + 0.002035 \cos 4 (5 \text{ deg. } 4 \text{ min.} + x).$$

$$\alpha = 0.127 + 0.00696 \cos (120 \text{ deg.} + x) + 0.0149 \cos 2 (-13 \text{ deg. } 2 \text{ min.} + x) + 0.03375 \cos 3 (8 \text{ deg. } 40 \text{ min.} + x) + 0.00949 \cos 4 (-44 \text{ deg.} + x).$$

$$\eta + \zeta = 0.127 + 0.00445 \cos (229 \text{ deg. } 52 \text{ min.} + x) + 0.0301 \cos 2 (4 \text{ deg. } 38 \text{ min.} + x) + 0.0460 \cos 3 (11 \text{ deg. } 20 \text{ min.} + x) + 0.01145 \cos 4 (-43 \text{ deg. } 18 \text{ min.} + x).$$

In these formulæ, 0.127 represents the constant angle of torsion between the two end sections, due to the constant tangential force of 34,760 kilograms.

The curves for α, β, and $\eta + \zeta$, of Figs. 12, 13, and 14, should, I think, demonstrate with sufficient clearness how much the law of the distortion of the shaft, when derived dynamically, deviates from the conclusions to which statical considerations lead us even under conditions like those of our example, when we have to deal with forced vibrations, somewhat remote, as regards their frequency, from the natural vibrations of the shaft.

Before finishing this paper I may be allowed to point out that the same method which is here applied to problems concerning marine engines may be used in the case of any other engine, especially for dynamos, for which we may likewise assume a proportionality between turning moment and angular velocity.

Conclusions.—Two rules may be laid down as self-evident conclusions to be drawn from these deductions, already stated by the above-mentioned authors.

(1) The force with which the engine acts on the shaft should be kept as uniform as possible.

(2) We should avoid the continued application of revolutions of the engine which bear a simple ratio to the frequency of the natural vibration of the shaft.

Fig. 1.

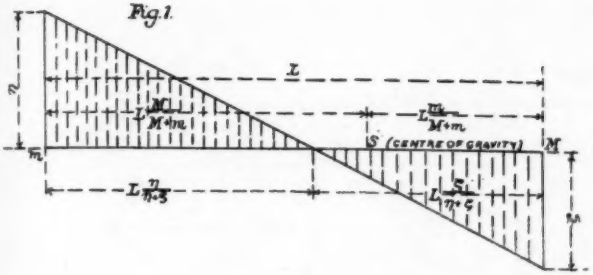


Fig. 2.

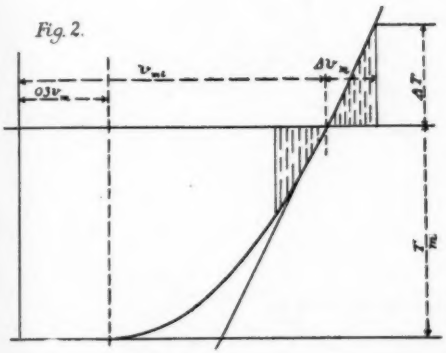


Fig. 3.

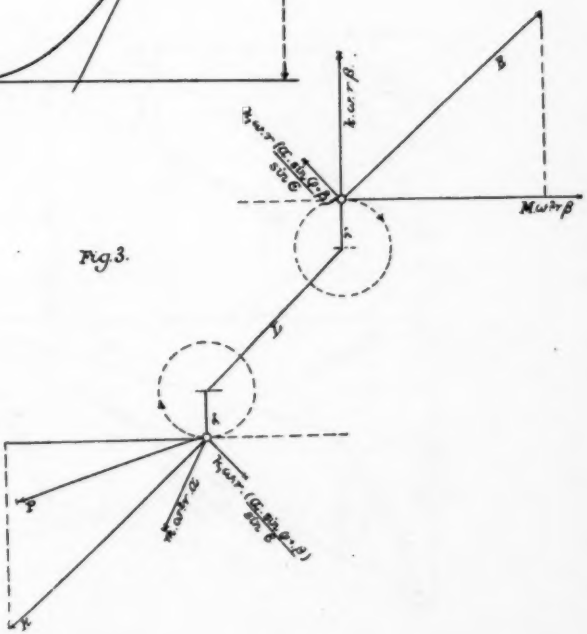


Fig. 4.

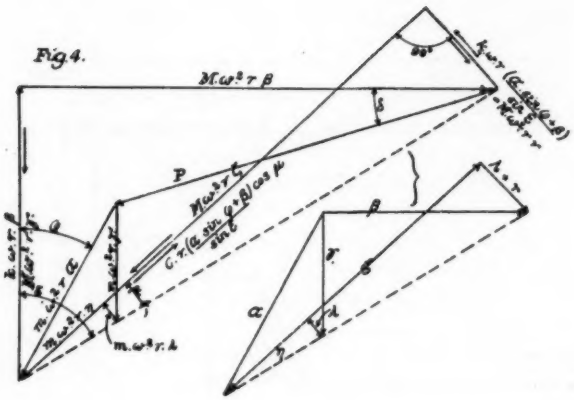

M.ω²r.β
P
M.ω²r.ζ
C.r(G sin(φ+β)/cos μ)/sin ε
k.ω²r.β
k.ω²r.α
m.ω²r.α
m.ω²r.η
m.ω²r.λ
m.ω²r.ξ
λ.ω²r
β
γ
α
δ

Fig. 5.

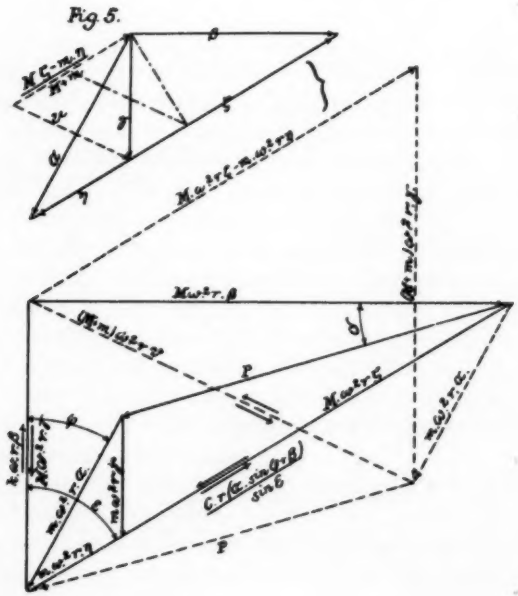

M(G−m.g)/M.ω²
M.ω²r(ζ−m.ω²r.η)
M.ω²r.β
(M−m)ω²r.ξ
P
M.ω²r.ζ
m.ω²r.ξ
k.ω²r.β
k.ω²r.α
m.ω²r.α
m.ω²r.η
C.r(G sin(φ+β))/sin ε
P

Fig 6.

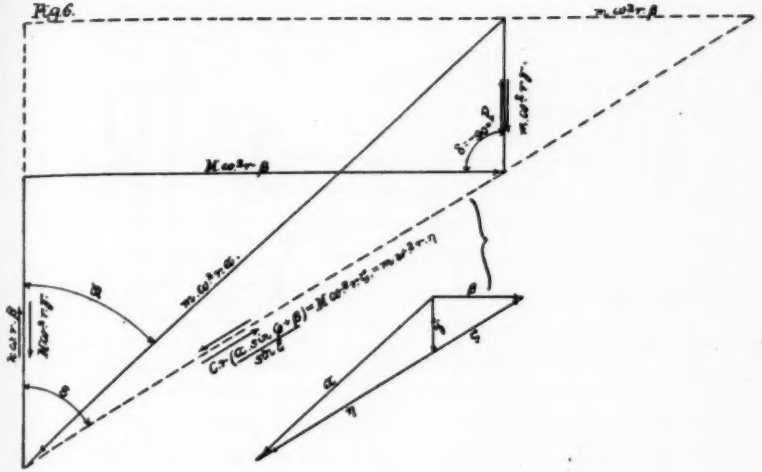


Fig 7.

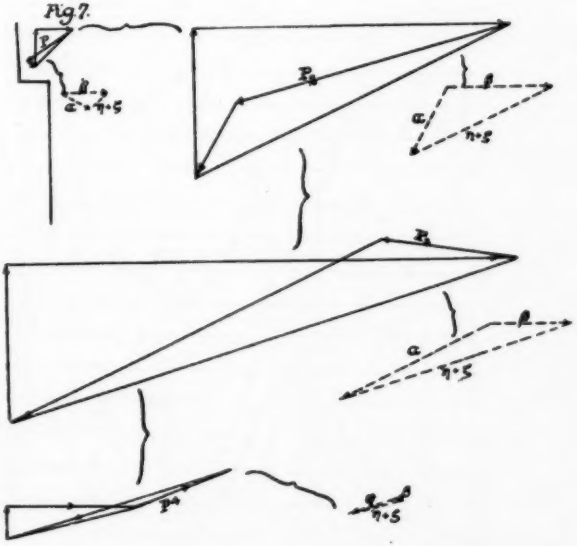


Fig 8

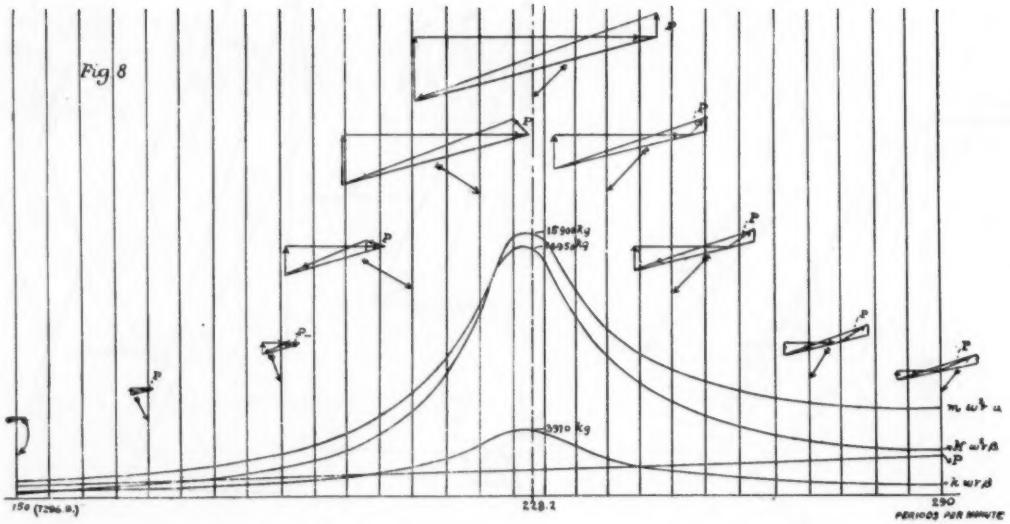

18900 kg
9905 kg
3910 kg
m ω² u
kr ω² β
kP
k ω² δ
150 (7296 p.)
228.2
290
PERIODS PER MINUTE

Fig. 9.

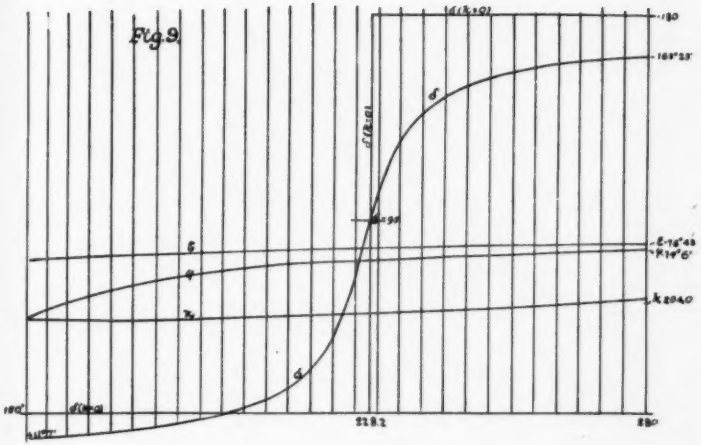
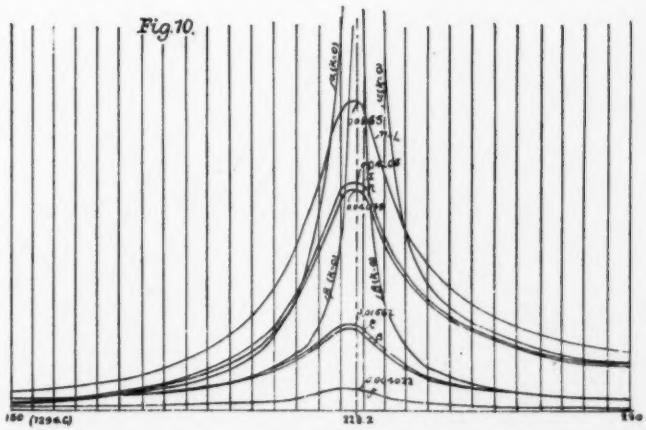
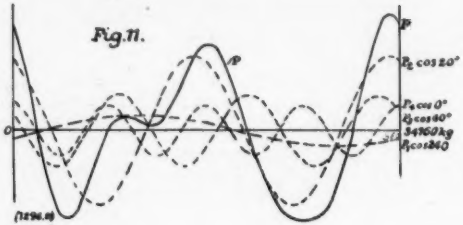


Fig. 10.



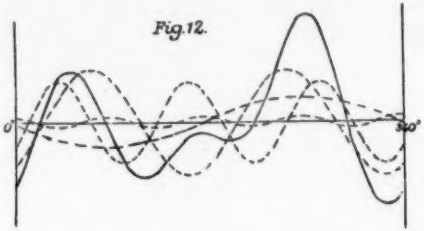
$P = 34760 + 1490 \cos(240° + X) + 1900 \cos 2(10° + X) + 3400 \cos 3(20° + X) + 2410 \cos 4(0° + X)$ (kg)

Fig. 11.



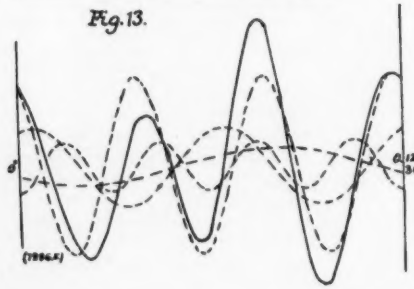
$\beta = 0.00346 \cos(33°40' + X) + 0.01953 \cos 2(167°26' + X) + 0.0155 \cos 3(77°6' + X) + 0.002035 \cos 4(5°4' + X)$

Fig. 12.



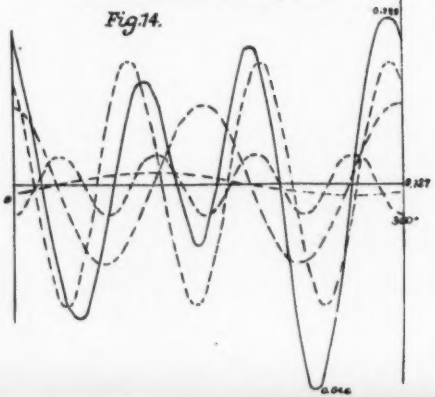
$\alpha = 0.127 - 0.00686 \cos(120° + X) + 0.0149 \cos 2(-13°2' + X) + 0.03315 \cos 3(8°40' + X) + 0.00949 \cos 4(-44°0' + X)$

Fig. 13.



$\eta + \zeta = 0.127 + 0.00445 \cos(229°52' + X) + 0.0301 \cos 2(4°38' + X) + 0.0460 \cos 3(11°20' + X) + 0.01165 \cos(-43°16' + X)$

Fig. 14.



The following addition may, in my opinion, be made to these simple rules.

(3) We should determine the possible tangential force diagrams for that number of revolutions likely to be adopted in practice which is most exposed to vibrations, and then ascertain, with the aid of the simple formulae developed, whether the resulting distortions $(\eta + \xi)$ of the shaft will remain within admissible limits.

ELECTRIC TRANSMISSION OF POWER FOR NAVY YARDS.—I.

By William S. Aldrich, Member.

Electricity is being introduced into manufacturing establishments at an accelerating rate of progress. At first used for shop and office lighting, later for small motor service from the lighting circuits, it has now come to be the recognized agent for the transmission and distribution of power in almost all industrial operations. There are very few new factories, mills and shipyards where it is not the chief means so employed. In many of them it is designed to make this the sole system for all power distribution about the works.

Meanwhile the rehabilitation, the modernizing of old establishments goes on apace. Costly and cumbersome belt transmissions are taken out to make way for the electric system, affording better shop lighting and ventilation and clear overhead room for traveling cranes. Fixed overhead shafting and pulleys are replaced by flexible wires and portable electric motors. For almost all kinds of machine work, beyond a certain size, motor-driven tools are now taken to the work rather than move the work about to the several fixed tools. Electric power is thus supplied, in the most economic manner, where most needed, and used only when required. The inevitable constant losses in any power transmission are reduced to the lowest value in the electric system. The maximum output is secured, on whatever basis it be reckoned—per day, per man, per machine or per square foot of floor space. Economy of manufacturing is guaranteed by increasing the quantity and enhancing the quality of the product, while decreasing the cost of production. If these, among many other well-known advantages of the electric drive have been recognized by private concerns, to what extent is it likely that they

will become determining factors in the power equipment for Government work, as in navy yards?

A navy yard necessarily combines the work of a private shipyard and a manufacturing establishment, on the one hand; and, on the other, that of a naval base and repair station. This composite nature of its work is subject to wide and frequently extreme variations. It must have equipment on hand and men within reach for all classes of work in marine engineering and naval construction. To secure the highest efficiency of management and greatest economy of maintenance, both workmen and tools should be kept quite regularly employed. This implies steady productive work on the part of the Government akin to that of private concerns. Moreover, to meet the demands of naval repair work and the exigencies of war when they arise, there must be within easy reach a certain reserve of men, tools and power facilities.

The economics of production dictate one type of power installation and management. Naval repairs seem to require quite another type. We shall show, however, that to secure the highest efficiency (using this word in the broadest engineering sense), electric-power transmission serves the same ultimate purpose in naval repair work that it does in manufacturing. The latter is a steady load on any power plant, the former an occasional one. The large and constant mechanical friction losses due to shafting transmission are ever to be reckoned with. This is the case, whether the plant is busy or running light, whether it is manufacturing or engaged largely in repair work. It is the special province of the electric system to reduce all such losses to a minimum. It occasions no lost power in transmission or distribution during the idle periods of intermittent and repair work. It is ever ready to meet any demand for increased power and extension in any direction owing to the extreme flexibility of the system. These advantages, therefore—the ability at any time to work machines and tools to the limit of production at any location desired and to any extent within the capacity of the power plant—make the electric drive an ideal system, as well for steady work as for emergencies and repairs.

The naval events of our late war with Spain clearly showed the importance of the time element in preparation for service afloat. Ordinarily, men and material, tools and facilities may be had for the asking or for the advertising, especially for government work. The qualifications of the men required special investigation at such a time. Materials and tools not found in stock among private concerns could not be obtained when most needed in fitting out work. The power facilities and productive capacity of our navy yards, with the old systems of belting and shafting transmissions, could not be increased on demand. The time element is an equally important factor in each one of the above necessities. For successful navy-yard work on such occasions as these, the interests of the public service demand the highest efficiency throughout.

A state of war brings about conditions in navy-yard work similar to those found in private establishments in seasons of rush orders and at the height of the busy season. The inability to meet these conditions in the former case scarcely elicited any public comment. Similar inability in manufacturing work would result in loss of further orders from the same source. It is the unexpected, the condition of maximum demand, which must be provided for, in either case. During the spring and summer of 1898, such navy-yard work as was done in line of production, overhauling, repairing and fitting out of vessels for the regular and auxiliary naval service was almost without exception accomplished at the old regulation or standard gait of all navy-yard work—at a pace established by a third of a century of peace. How could it be accelerated? With the very best intentions what could be done in the matter of expediting the work, with the accumulated traditions of that golden age for the navy-yard mechanic? Even those workmen who did not consider it a crime to speed up their machines could not, if they wished, meet the demand for increased capacity with fixed speeds of main-line and counter-shafting overhead. Neither could they get all of the power which they might require at any point and at any time to meet the conditions for maximum all-round efficiency in the execution of their work.

The element of time is destined to be of supreme importance. This is now the case in all of the arts of production. It is coming to be the case in the arts of destruction. Conditions may arise in either situation where it becomes the deciding factor. That establishment which can guarantee delivery of its products gets the business. The nation whose war vessels, before going into service, can be put through the usual navy-yard régime in the shortest possible time has an enviable strategic advantage. With the manufacturer it is a question of commanding the trade, of accepting and filling orders, or of losing the business to those who can. With the Government it is a question of commanding the seas, by quickly getting its vessels ready for service, or of losing the command to that nation which can and does have its vessels ready for war. Even the peaceful operations of a navy yard frequently require work to be executed by the quick-dispatch method. Were this not the case, slow-moving shafting and slow-speed machines would ever seem to suit the navy-yard mechanic, regardless of how and why they have now been discarded by the best, the most successful private establishments. If the efficiency of electric-power transmission, economy at the coal pile, increased output at decreased cost of production, have decided the private concern in its favor, these are none the less helpful factors toward deciding the case for its introduction in Government work.

The engineering work of the Government calls for the highest efficiency, in whatever field and from whatever point of view it may be considered. In the navy yard it is not simply the question of the efficiency of power transmission that is enhanced by the adoption of the electric drive; it results in increased efficiency of workman, of tool, of the whole process of production. Its inherent advantages for this field outweigh all of the old debatable questions of shafting efficiency and of coal economy. When work is required by the Government to be done it must be done. That system which secures its execution in the most efficient and expeditious manner must commend itself for adoption. Facilities for rapid repairs at the navy yard constitute as much an element

of sea power as provisions for rapid fire in action, and are to be similarly reckoned with.

Efficiency, as it is understood to-day, in the larger engineering sense, not only includes but demands expedition. This is one of those engineering terms which has lately expanded in its meaning and value. The simple statement of the school books defines efficiency as the numerical ratio of the work done to the power available. The comprehensive meaning of efficiency in relation to naval power is thus summed up by Captain F. E. Chadwick, U. S. N., the commanding officer of Admiral Sampson's flagship, in reference to the service rendered his fleet in Cuban waters by the U. S. Naval Repair Ship *Vulcan:*

"No one can understand the value of such an adjunct who has not had to look around for ships to go on duty, the long list of waiters for repairs or overhauling was sometimes heartbreaking; a full third of such a fleet as ours had at all times been counted off as unavailable for such reasons and others."

What manufacturing establishment, with a complement of men and a trained personnel, could pay wages, much less get out orders and keep its business, with a full third of its material equipment at all times to be counted off as unavailable? These conditions, exasperating enough in times of war, are none the less likely to arise in seasons of nominal peace, and of unprecedented prosperity throughout the country. Such a season is the present. Perhaps it may be the case, or may sometimes be proven to be the case, that the most noted living steel-maker has correctly judged of the United States in saying that it cannot be conquered, so long as its integrity is maintained, from the Atlantic to the Pacific, from the Lakes to the Gulf, with its almost unbounded resources of men and material, and its industries now so fully organized to develop both to the highest degree of productive capacity.

The use of electricity in navy yards is destined to be much farther reaching than merely to provide a more efficient system of power transmission. From all considerations in which it may be viewed it may be said, without a dissenting argument, that its introduction will inure to that more comprehensive efficiency

in times of peace as well as of war. It will have an indirect strategic importance not yet tested in action, but now so thoroughly proven in the exigencies of business and the keen competition of trade. The efficiency of production now secured in manufacturing work spells economy. The efficiency of service to be secured by its introduction in navy yards will spell readiness. Dollars constitute the measure of value for business. Strategic advantage constitutes the measure of value for sea power. The manufacturer asks: Will it increase dividends? The Government asks: Will it increase sea power?

The technical discussion of this subject is not new to these columns or its readers. Nor is it likely that the last word will soon be spoken in such a field as the industrial applications of electricity. A few of the principles and advantages of electric driving established in private concerns may seem inapplicable to the navy-yard power problem. On the other hand, there are special advantages accruing to its use in such a place that would certainly not decide its introduction in manufacturing work. It is not to be inferred that electric-power transmission should be introduced in the navy yard at any cost. But, for the purpose for which a navy yard exists, it may be said that no system of power transmission has yet been developed possessing so many advantages and so few disadvantages as the electric system. It is thoroughly adapted to meet the largest variety of functions of this class of engineering work. For a limited class of mechanical movements, chiefly reciprocating, and for certain operations, as pressing, forging, flanging, riveting and caulking, steam, compressed air and hydraulic pressure will no doubt continue to be used.

The power characteristics as well as economic considerations require to be carefully detailed in each and every kind of productive work. To this the navy yard offers no exception. The program for the execution of its work should in no wise be influenced by the question of power transmission. The reverse should be the case. The system of transmission should be determined by, rather than itself determine, the conditions for most efficient and economic production. The latter involve the area

to be served by work or portable tools, or both at the same time; the grouping of departments; the arrangement of machinery; the style, type and size of machines and tools; the number and kind of operations to be performed simultaneously; the cutting and other operative speeds; the character of loads and their variations; the kind of work to be executed and materials to be employed. The system of power transmission adopted should not in the least interfere with the natural development of any one of the preceding elements of production. It should, if possible, enhance their relative or absolute importance.

Electric power in shipyards has proven its value for this class of work, especially during the past four years. It has been severely tested in everyday work, and not found wanting. One of the special reasons for this result has been its adaptation in serving power to widely distributed points and groups of buildings. It has insured greater freedom, a larger degree of movement in almost all branches of ship and engine construction. Electric motors now economically perform the work of many small and scattered steam engines of the old type of shipyard. The cost of power by distributed steam-engines is to-day prohibitive in private yards, compared to the economies effected by concentrated steam-power generation. In so far as private and Government yards have such work in common, can the latter continue to employ antiquated methods of power distribution?

The wandering of work is likely to be excessive in such widely scattered buildings as exist in shipyards. It has at last been minimized, if not altogether obviated by the use of electrically-driven portable tools—one of its adaptations specially invited by the extreme flexibility of the system. The similar movement of men and material has always constituted a like disadvantage in shipyard work, to which the electric system has applied an efficient and economic check. It has been especially in the matter of dock repairs that the problems of lost time between shop and ship defied any solution till the introduction of portable tools. Any radius of action may be maintained at any time, and to any amount of power needed, and with less time required by the electric than by any other system for shifting of workmen, tools and

material. Moreover, it admits of simultaneous operations, by portable tools independently driven or operated.

Before proceeding to a detailed study of the application of electrical transmission in this field it will be helpful to make a general survey of what may be termed the navy-yard power problem. It goes without saying that such a problem is of necessity quite comprehensive. It involves considerations not to be found in private establishments and shipyards. From its functions, as related to the public service, there is no peculiar obligation to serve commercial interests. Irrespective, therefore, of what system may be best in special instances, let us outline some of the conditions to be met in any case regarding power supply for a navy yard. It will be understood that every system, either proposed or adopted—as steam, compressed air, hydraulic pressure, wire rope and electricity—furnishes one or more of the suggested requirements composing any such general survey.

No one system will solve the entire problem, expanding, as it is, in many directions simultaneously. Each year's experience furnishes new and more exacting requirements. That system which meets the largest number of conditions at the given time of its installation will be the best for that time. There is no guarantee but that in a decade or less it may become antiquated. We refer to the system becoming antiquated, not the equipment, machinery and appliances required for its utilization. These latter, of course, will have to be put into the scrap heap, sometime, in any system, unless the Government's navy yards are to become more interesting museums for mechanical curiosities than they are now. Waiving all other considerations, this question of replacement or scrapping is probably the last one to be carried out in these yards, though now so common in private establishments for various recognized economic reasons.

Military and strategic considerations:

To secure maximum efficiency of all navy-yard work by meeting the routine or emergency speed and power requirements necessary for intensified production, for any length of time and in any location within the yard enclosure.

To secure rapid interchangeability throughout the system, by

standardization and duplication of units, elements and spare parts.

To admit of rapid and non-interfering extension and expansion of power facilities for any kind of navy-yard work, either on peace or war footing.

To reduce to a minimum all delays due to accidents, casualties and shutdowns inherent or peculiar to navy-yard work, that they may be easily and quickly made good without interfering with or stopping any part of the system.

Naval-shop repairs to be accompanied by no losses or wasteful operations during necessary idle periods of intermittent work; and dock repairs to be efficiently and readily executed by portable tools and shop appliances.

The power transmission and distribution system between shops, departments or buildings, to be kept out of all danger of the enemy's fire.

To reduce to a minimum all fire risks, delays, casualties due to enemy's shells.

To continue all operations by supply of power from distant point, out of reach of an enemy, if the local navy-yard plant shuts down for any reason during a public exigency.

To reduce to a minimum, especially during war, the necessity for supervision, superintendence, repairs, renewals, replacements of units or parts of the same.

To best conserve the health, morale, discipline of all workmen that their individual efficiency may be kept at a maximum and fewest men required to execute any given work, especially during war.

Centralized generation of power: Power plant to be located in an isolated house, reducing danger of fire from nearby sources; preferably by a water front for economy of fuel and water, and to secure transportation and conveying facilities for fuel, ashes and machinery.

Transmission system to be simple, flexible, reliable, convenient of application through wide ranges of load requirements and necessary speed changes of machinery and tools; and to possess

inherently a wide range of other applications to serve the functions of a navy yard.

Equipment to admit of ready duplication, interchange and extension; that the generating units may be operated always at the most economic normal loads; that extensions of the transmission system may be made at any time, to any point and in any capacity; and that measurements of power wherever and whenever required may be readily made.

Re-organization of the power equipment of existing navy yards to be interfered with in the least by introducing the new system, which must be such as to require the least scrapping of machines and tools.

Expansion of shop facilities and arrangement of machinery and tools to better productive advantage, to be provided by new system, with such location in groups and shops as shall secure maximum output per square foot of floor space, rendering the location of shops and departments independent of the power consideration, that they may be placed on most available ground, within necessarily limited areas of the navy-yard enclosure.

Initial cost to be reasonable, but not necessarily the least expensive to be chosen, regardless of efficiency and cost of maintenance; and, while saving power, the interest, depreciation, repairs and renewals should be reduced to a minimum.

Operating features to permit of several simultaneous lines of work being executed on any project by portable tools; to allow of clear overhead room for traveling cranes; to allow of individual, group or sectional driving, as may be best suited to the machine or work in hand; and, if individual driving is adopted, to allow of wide, easily-controlled range of speed changes for maximum productive capacity of machine or tool; and to supply power for auxiliaries and transportation.

In the system of transmission adopted, other applications than those of supplying power should, if possible, consist in supply of heat and light as required in a navy yard.

SECOND REPORT OF THE BOILER COMMITTEE ON THE TRIALS OF THE *HYACINTH* AND THE *MINERVA.*

Reprinted from London "Engineering."

The Committee on Water-Tube Boilers issued an interim report last year which has been fully considered in our columns. We mentioned last week that a second interim report had been "issued." It was not published, however, until the 28th instant. It is a Blue-book of considerable size, mainly composed of tables and diagrams. The tables contain thousands of figures. The diagrams do not appear to possess any general interest. It is possible, however, that the tables may be of special value. To us their principal use appears to be the evidence which they give of the industry of the staff employed to obtain the particulars tabulated. We do not, ourselves, think that any good end is subserved by reproducing in a Parliamentary Blue Book, the half-hourly record of the performance of a set of marine engines filling 36 columns, each line involving the use of about 96 numerals. Seeing that there are 28 lines in the table, we have an appalling total of 2,688 numerals. Some of the tables contain fewer figures. But, after all, no exception need be taken to the figures if they supplied useful information. They do nothing of the kind. We believe that we shall utilize our space to better purpose by telling our readers the story that the Committee has set forth, and by drawing what appear to be legitimate deductions.

Much of the present report repeats somewhat more in detail the account of the trials of H. M. S. *Hyacinth* with Belleville boilers, and H. M. S. *Minerva* with Scotch boilers, last July. A most notable feature of the present report is the account which it contains of the result of a trial made with the Cunard Company's ship *Saxonia*, on a run from Liverpool to Queenstown at about 9,000 indicated horsepower, on the 5th and 6th of Feb-

ruary, 1901. These results are very carefully compared with those obtained from the boilers and machinery of the *Hyacinth* and *Minerva*. The constructional particulars of the three sets of engines and boilers are set forth in the accompanying Table I.

Let us proceed to consider the nature of the lesson which the report as a whole teaches the world.

It is a matter of history that a determined and expensive attempt has been made to supersede the Scotch boiler in the Royal Navy with the Belleville water-tube boiler. The arguments advanced in favor of this change must be repeated here for the sake of ensuring lucidity.

First, the Bellville boiler being lighter than the Scotch boiler, and being competent to carry a very high pressure, must be better for fighting ships, the propelling plant of which must be kept down in weight. Secondly, the Belleville boiler can be put to work in much less time than the Scotch boiler, which cannot be forced with impunity, and, even if it were forced, would not be able to supply steam as quickly as the water-tube boiler. Thirdly, the Belleville boiler is more economically efficient than the Scotch boiler. Fourthly, it can be trusted not to break down, and the Scotch boiler cannot be so trusted. Fifthly, the water-tube boiler being able to carry a higher pressure than the Scotch boiler, the propelling plant will be on the whole more economical than the machinery working at a lower pressure with cylindrical boilers. There have been other arguments advanced on the side of the water-tube system; we need not define them. Those of our readers who are interested in the subject will admit that we have stated all the principal arguments in favor of the Belleville boiler.

The peculiarity of the report before us is that it refutes every one of these contentions in the most complete way possible. It is within its limits a comprehensive and conclusive condemnation of the modern system of propelling ships of war in the British Navy. It does not cover all the ground; it does not deal with every possible condition of mechanical construction or sea service. It cannot do that—no single report could do that. It supplies

TABLE I.—PARTICULARS OF HULLS, MACHINERY, ETC., OF

Name of ship	H. M. S. *Hyacinth*.
Date of contractor's trial	1899
Builder's name	London and Glasgow S. B. Company
Description	Second-class cruiser
Length between perpendiculars	350 feet
over all	373 feet
Beam	54 feet
Displacement	5,600 tons
Draught at this displacement, Forward	19 feet 6 inches
Draught at this displacement, Aft	21 feet 6 inches
Draught at this displacement, Mean	20 feet 6 inches
Main engines, description	Vertical triple expansion
Maker's name	London and Glasgow S. B. Company
Number of cylinders and cranks	4
Diameter of cylinders, H.P	26 inches
Diameter of cylinders, I.P	42 inches
Diameter of cylinders, L.P	2 of 48 inches
Diameter of piston rods	*Star.* / *Port.*
	H.P....6.613 inches; 6.622 inches
	I.P.....6.615 inches; 6.556 inches
	F.L.P..6.620 inches; 6.620 inches
	A.L.P..6.113 inches; 6.621 inches
Length of stroke	2 feet 6 inches
Designed maximum steam pressure	250 pounds square inch
Auxiliary engines can exhaust to	L.P. receivers, evaporators, auxiliary condensers and atmosphere.
Boilers, maker's name	London and Glasgow S. B. Company
Description	Belleville
Number of boilers	18
furnaces	18
Length of fire grate	5 feet 6⅞ inches
Width or diameter of furnaces	7 feet 10½ inches
Total area of fire grate	792 square feet
heating surface	Generator, 16,380 square feet / Economizer, 8,046 square feet
Safety-valve pressure	320 pounds square inch
Tubes, Diameter	Generator, 4 inches / Economizer, 2⅜ inches
Tubes, Length between tube sheets for junction boxes	Generator, 5 feet 10⅞ inches / Economizer, 5 feet 1⅛ inches
Tubes, Pitch	Generator, 5⅛ H., 5⅛ V / Economizer, 3⅛ H., 4⅛ V
Type of ferule fitted to tubes	
Are retarders fitted to tubes?	
Howden's forced-draft system:	
Tubes, Number	
Tubes, Length	
Tubes, External diameter	
Tubes, Total surface	
Ratio, Boiler tube surface / Air-heating tube surface	
Stokehold fans, Number	6
Stokehold fans, Diameter	5 feet 6 inches
Funnels, Number	3
Funnels, Inside diameter	7 feet 3 inches
Funnels, Height above dead plates	75 feet
Propellers, Twin or single	Twin
Propellers, Number of blades	3
Propellers, Diameter	13 feet 1¼ inches
Propellers, Mean pitch	13 feet 3 inches
Propellers, Immersion, upper edge	5 feet 7½ inches for 21 feet 7 inches draught

H. M. S. *HYACINTH*, H. M. S. *MINERVA* AND R. M. S. *SAXONIA*.

H. M. S. *Minerva*.	R. M. S. *Saxonia*.
1896	1900.
Chatham Dockyard	John Brown & Co., Limited.
Second-class cruiser	Passenger and cargo steamer.
350 feet	580 feet.
373 feet	600 feet.
53 feet 6 inches	64 feet, moulded.
5,600 tons	22,580 tons.
19 feet 6 inches	
21 feet 6 inches	
20 feet 6 inches	29 feet.
Vertical triple expansion	Vertical quadruple expansion.
Chatham Dockyard	John Brown & Co., Limited.
3	4.
Star. *Port.*	
33.0937 inches; 33.1093 inches	29 inches.
49.1662 inches; 49.5370 inches	First int., 41.5 inches; second int., 39 inches.
74.0000 inches; 74.9000 inches	84 inches.
Star. *Port.*	
H.P....6.8437 inches; 6.9828 inches I.P....6.7500 inches; 6.9828 inches L.P....6.9516 inches; 6.9375 inches	8.25 inches.
3 feet 3 inches	4 feet 6 inches.
150 pounds square inch	210 pounds square inch.
Auxiliary condensers and atmosphere	L.P receivers, auxiliary condensers, main condensers and atmosphere.
Chatham Dockyard	John Brown & Co., Limited.
Single-ended, cylindrical	Single-ended, cylindrical.
8	9 main, 1 auxiliary.*
24	27 main, 3 auxiliary.
7 feet	Main boilers, 5 feet 6 inches.
3 feet 10½ inches	Main boilers, 3 feet 10 inches.
649 square feet	Main, 570 square feet; auxiliary, 60 square feet.
18,464 square feet	Main, 25,803 square feet; aux., 1,663 square feet.
155 pounds square inch	210 pounds square inch.
2½ inches	2½ inches.
6 feet 8½ inches	8 feet 2½ inches.
3½ inches by 3½ inches	3⅞ inches by 3⅞ inches.
Admiralty	None.
Yes; at Boiler Committee's request	Yes.
	2,394.
	4 feet.
	2⅞ inches.
	6,894 square feet.
	3.2 : 1.
8	2.
6 feet	8 feet 9 inches.
2	1.
Oval, 8 feet by 6 feet	Oval, 15 feet 4 inches by 12 feet.
75 feet	129 feet 9½ inches.
Twin	Twin.
3	3.
13 feet 9 inches	19 feet 6 inches.
17 feet ⅛ inch	20 feet 6 inches.
5 feet 3 inches for 21 feet 7 inches draught	8 feet 6 inches for 29 feet draught.

* *Saxonia*.—Main boilers only included in Committee's trial.

the record of conclusive evidence afforded by the performance of three typical ships, and that evidence is, as far as it goes, condemnatory of the Belleville boiler and the high-speed, short-stroke engine. It may be urged that the ships are not typical. There may be better vessels than the *Hyacinth*, better vessels than the *Minerva* or the *Saxonia*. That is quite another story. As we have said, the report as it stands is conclusive, within its limits of experience, and just now we have nothing to do with anything else outside this report.

We will take the arguments we have defined above seriatim, and show what the report has to say about them.

(1) *The Use of the Belleville Boiler Secures a Reduction in the Weight of the Propelling Plant.*—It is obvious that the words "propelling plant" include not only the engines and boilers, but the auxiliary machinery, coal and spare water that have to be carried. The following table gives the weight of the machinery of the three ships:

WEIGHTS.

Parts.	H. M. S. *Hyacinth*. Tons.	H. M. S. *Minerva*. Tons.
Main engines with propellers, spare parts, and evaporating and distilling plants	378.4	364.8
Boilers with funnels, spare parts, and hot water to working height; also pipes, fans, feed engines, and all boiler-room weights	453.8	557.4
Total	832.2	922.2

R. M. S. *Saxonia*.

Parts.	Weight. Tons.
Main engines	789
Main boilers, including water at working level, Howden's fittings, uptakes and funnel	910
Auxiliary machinery in engine and boiler rooms, evaporators, &c.	60.3
Remainder, including steam and exhaust piping, floor plates, ladders, platforms, &c., in engine and boiler rooms	176
Spare gear in engine and boiler rooms	50
Total	1,985.3

For the moment the comparison lies between the *Hyacinth* and the *Minerva* only. There is a saving in weight amounting to 90 tons, secured by the use of water-tube boilers and high-speed engines. This is not a very important saving. It is partly balanced by the fact that the *Minerva*, notwithstanding the additional 90 tons, could carry 1,016 tons of coal, as against 998 tons for the *Hyacinth*, or 48 tons more. In addition to this, the *Hyacinth* carried 140 tons of reserve fresh water and the *Minerva* about 170 tons. It is said that the radius of action of a ship is determined by the quantity of coal she can carry, and that the lighter the engines and boilers the greater the quantity of coal. The report of the Committee does not bear out this contention. Dealing with the Gibraltar runs, it says: "It was anticipated that the radius of action of the ship at 7,000 horsepower would be limited solely by the coal expenditure. It has turned out, however, to be limited by quite another set of conditions, depending not on coal consumption, but on the excessive loss of water. The distance run when the trial had to be stopped on this account was 1,810 miles, which represented the actual radius of action of the *Hyacinth* at 7,000 horsepower. It would, of course, be easy to work out arithmetically a hypothetical radius of action, assuming that the ship could have continued working at the same coal consumption per horsepower until her coal was exhausted; but, especially in view of the result of the homeward voyage, the Committee do not think that such a figure would have any practical value, or give a real indication of the performance of the vessel." A little further on the Committee say on this important question of weights: "In reference to the figures representing horsepower developed per ton of weights, it seems important here to point out that the total difference between the engine and boiler weight in the two vessels is 90 tons out of a displacement of 5,600 tons. But, in the full-power run home from Gibraltar, the *Hyacinth* burnt 90 tons more coal than the *Minerva*, at nearly the same average power, and used also 58 tons of special storage water. Her initial displacement due to machinery was, therefore, for the three days run, not 90 tons less, but about 60 tons more than that of the *Minerva*. On the run out at 7,000 horse-

power, the coal per horsepower in the two ships was practically identical, so long as the *Hyacinth* could run at that power. The only thing that could have enabled her, however, to complete her trial by continuing to work at 7,000 horsepower until all coal was burnt out would have been an extra weight of water carried in her double bottoms. The exact weight is uncertain, but it would have been much more than 90 tons. *On neither of the two runs, therefore, could any advantage have been taken of the 90 tons of weight nominally saved.*" The italics are ours. It would be quite easy to push the argument much further; we do not think, however, that it is necessary to do this. The report is conclusive that nothing whatever is to be gained in the way of a reduced displacement by the adoption of the Belleville boiler and high-speed engines.

(2) *Steam can be Raised Much More Rapidly in the Belleville than in the Cornish Boilers.* We reproduce the graphic account of what actually took place at Gibraltar to settle this question.

"The *Hyacinth* anchored in the bay at 4·30 P. M. on the 16th July, and all her fires were drawn except those in two boilers. It was decided to allow her sufficient time after anchoring to sweep tubes, &c., after the run of the 16th, and it was settled that the start home should not be made before 4 P. M. on the 17th July.

The *Minerva* arrived at Gibraltar at 12·30 A. M. on the 13th July, and came alongside the Mole at 7·30 A. M. that day. Steam was off the ship entirely from noon on the 14th to noon on the 15th. On the forenoon of the 14th the boilers were sufficiently cool for men to work in the combustion chambers and chip off the slag from the tube plates and ferrules. The bridges and brickwork were found only to require touching up with fireclay for the homeward run. There was no sign of leakage in the back ends, and the fire grates were in fairly good condition. The uptakes and smoke boxes were thoroughly cleansed and the combustion chambers scrubbed with wire brushes.

To admit of safely handling the *Minerva* out to her anchorage on the 16th, three boilers were used, viz: Nos. 1, 2 and 6.

During the 17th, both vessels lay at anchor in the bay, having

been told that on a signal being made at an unknown time after 4 P. M. by the senior officer at Gibraltar, fires were to be lighted in the boilers not at work, and the ships were to proceed to Portsmouth independently as fast as possible.

Before the ships began the homeward run a communication, as follows, was handed to the captain of each ship:

"On the responsibility of the ship's officers, a large quantity of fresh water for boiler makeup has been taken as a precautionary measure in the double bottoms of the *Hyacinth* and in the extra reserve tanks in both ships. These latter tanks were fitted specially for the outward trial, and do not form a part of the ships' ordinary fittings. It is to be understood that, except the amount originally allowed in each ship—about 40 tons in the ordinary reserve tanks—this is to be used in cases of emergency only during the homeward run. The evaporators, if they have not been in use before, are to be started as soon as the 40 tons mentioned have been used up, and then the makeup required is to be obtained from the evaporators. If the evaporators are unable to supply the whole of the makeup required, their use at maximum obtainable output is to be maintained, while the remaining water used may be taken from the reserve tanks."

The condition of affairs in the *Hyacinth* on the 17th up to the time of starting was as follows:

"5·45 A. M.—The main stop valves in engine rooms just warm to the hand. Two boilers, Nos. 14 and 17, were under steam, one at 120 pounds and the other at 105 pounds pressure. The other sixteen boilers had all the grates raked clean. The generator and economizer tube-nest doors were all shut. The lower generator tubes were slightly warm to the hand. The boiler casings in way of firebrick linings were all hot to the hand. There was about 2 inches of water in each gauge glass.

"12·50 P. M.—The main stop valves on the engines were cooler than in the early morning. The two boilers under steam showed 200 pounds pressure; the other sixteen boilers had the grates wooded and coaled. All tube-nest doors, both generator and economizer, shut; but most of the furnace doors were wide open. These sixteen boilers now cooler than in the early morning.

"3·5 P. M.—The steam gauge on the engine side of each set of main engines reducing valve showed 25 pounds pressure. Blowing engines working on both the boilers under steam. The other sixteen boilers in the same condition as at 12·50 P. M.

"3·17 P. M.—The steam gauge on the engine side of the reducing valve of the port set of main engines showed 76 pounds pressure; the corresponding gauge of the starboard set showed 95 pounds. All cylinders being warmed up by the jackets; the average pressure in these latter, 10 pounds.

"3·25 P. M.—The reduced steam gauge on both sets of engines showed 115 pounds.

"3·26 P. M.—The links of port engine moved, and both engines moving ahead and astern under steam at 3·30 P. M.

"3·45 P. M.—The two after stokeholds were closed down and the fans run hard. The sixteen boilers not in use remained unaltered, except that a priming of oakum steeped in inflammable oil was inserted in the mouth of each furnace.

"4·15 P. M.—The steam pressure in the two boilers in use, 240 pounds.

"In the *Minerva* during the same period the conditions were as follows:

"At 7·45 A. M.—There was 20 pounds of steam in No. 2 boiler, and 15 pounds in No. 1; the fires of both these boilers had been drawn over night. The smoke-box doors were all shut in those two boilers, and the grates were being wooded and coaled. The other five boilers, which had not been in use to steam to the anchorage, had all the smoke-box doors and ashpit dampers shut, the grates were all wooded and coaled, and the furnace doors had all catches lashed, the object evidently being to prevent the doors being opened and the boilers cooled. The water had not been changed in them after arrival at Gibraltar on the 13th of July, and they were still slightly warm to the touch. No. 6 boiler, which was the one allowed to be under steam according to the instructions, had 40 pounds pressure in it. The main stop valves on the engines were barely warm to the hand.

"At 1·30 P. M.—No steam was showing on the pressure gauges at the engines. The main stop valves on engines were so hot

that the hand could not be borne on them. The main circulators were running slowly. The main condensers were quite cold. No. 6 boiler now had 80 pounds of steam, and the fires were being thoroughly cleaned. Nos. 1 and 2 boilers showed no pressure, but they were still quite hot. The other five boilers were in the same condition as in the morning, and certainly no hotter; there was about 2 inches in each glass gauge.

"A little later the engines were warmed through by steam from the boiler which was in use.

"At 4 P. M. the temperatures of the water in the boilers of both ships were taken and found to be as follows: *Hyacinth*, (No. 1) 90°, (No. 2) 90°, (No. 3) 92°, (No. 4) 90°, (No. 5) 94°, (No. 6) 92°, (No. 7) 94°, (No. 8) 96°, (No. 9) 96°, (No. 10) 88°, (No. 11) 90°, (No. 12) 92°, (No. 13) 94°, (No. 14) at work, (No. 15) 104°, (No. 16) 98°, (No. 17) at work, (No. 18) 109°; giving an average temperature of 94¼°. *Minerva*, (No. 1) 164°, (No. 2) 180°, (No. 3) 104°, (No. 4) 104°, (No. 5) 98°, (No. 6) at work, (No. 7) 100°, (No. 8) 108°; giving an average temperature of 122½°, or 28¼° higher than that of the *Hyacinth*.

"The signal to start was made at 4·27 P. M., on July 17th.

"The sixteen boilers of the *Hyacinth* which were standing were lighted immediately, and the main engines started slowly moving ahead at 4·30 P. M. The after group of boilers was connected up at 4·52, the forward group at 5·05, and the middle group at 5·09, the steam pressure being 200 pounds per square inch. By 5·20, or 53 minutes from the signal, the ship was proceeding with nearly 7,000 horsepower, and at about 150 revolutions per minute. The work in the engine rooms and stokeholds was admirably carried out.

"The seven standing boilers of the *Minerva* were lighted up in the same fashion, and equally without flurry or hitch. The boilers were connected up as follows: No. 1 at 4·55, No. 2 at 5·02, No. 8 at 5·07, Nos. 4 and 7 at 5·10, No. 3 at 5·12 and No. 5 at 5·15. The engines were working approximately at full power by 5·16, or 49 minutes from the signal, practically the same time as the *Hyacinth*."

This very precise statement disposes forever of the myth that

steam cannot be raised in a hurry in Scotch boilers. The argument that even if it were possible to get steam in less than an hour it would be at the risk of injuring the boiler, is completely refuted by the fact that when the *Minerva* reached Portsmouth no leaking tubes whatever were found, and only six other leaks, described as "very slight." We have already explained in a former article how it comes to pass that steam can be raised so quickly in a Scotch boiler. It may, however, be worth while to say once more that because hot water is lighter than cold it is quite possible to have the upper strata in a cylindrical boiler in ebullition while the water below the furnaces is still cold. At this moment, however, we have nothing to do with theories. Hard facts alone concern us.

(3) *The Belleville Boiler is a More Economical Generator than the Scotch Boiler.*—The report before us does not support this view. The *Minerva's* boilers were at first less thermally efficient than those of the *Hyacinth.* The Committee explain why,

"At 2,000 and 5,000 horsepower, the *Minerva's* coal consumption per square foot of grate was somewhat less than that of the *Hyacinth;* but, at higher powers, the larger grate area of the *Hyacinth* reversed this ratio, so that at 8,000 horsepower, the *Minerva* was burning 30.3 pounds per square foot as against 19.8 on the *Hyacinth,* the latter ship only burning 27.2 pounds when indicating over 10,000 horsepower. The rate of transmission of heat through the heating surface varies similarly, being somewhat smaller in the *Minerva* at the lower powers and very much greater at the higher powers. The thermal efficiency of the *Hyacinth's* boilers was in each case greater than that of the *Minerva's* at the same power, and the evaporation per pound of coal from and at 212 degrees varied, of course, in the same way. The difference is considerable at 2,000 horsepower, small at 5,000 horsepower, and very great at 8,000 horsepower. Fortunately, the completeness of the observations made allows it to be seen at once both to what this difference was and to what it was not due. That it was not caused by the forcing of the *Minerva's* boilers appears from the result of the 2,000-horsepower trial, where they were working very easily. That it was not due to

incomplete combustion is also shown, this loss having been practically the same in the two ships at 8,000 horsepower. It appears to have been due entirely to the high funnel temperature and the excess of air in the furnace gases, with the consequent waste of heat up the funnel in the *Minerva* as compared with the *Hyacinth*. In the most marked case, viz: at 8,000 horsepower, the loss by incomplete combustion is practically the same in both ships, but in the *Minerva* the air used per pound of coal is nearly 30 per cent. greater than in the *Hyacinth*, and the gases are raised 180 degrees Fahrenheit higher in the funnel, the total funnel waste being just double."

So far this is against the *Minerva's* boilers. But we have to do, it will be remembered, with a wider field of comparison than this. The *Minerva's* boilers are five years old, and not in the best condition. They did not represent the maximum excellence to which the cylindrical boiler may attain. For that we shall have to turn to the *Saxonia*. Yet the Belleville boilers of the *Hyacinth* may be taken to represent the best and latest practice, and the comparison is so far not quite fair to the cylindrical boiler as a class, although it is fair to the *Minerva's* boilers. But subsequently a very small and inexpensive addition to the *Minerva's* boilers rendered them as economical as those of the *Hyacinth*. The tubes were fitted with retarders—that is to say, strips of hoop iron as wide as the inside diameter of the tubes, with two and a half twists in their length, namely, 6 feet 8¾ inches. These retarders compel the hot gases to twist round and round inside the tube, instead of rushing headlong to the funnel. The results obtained are very pronounced, as will be gathered from the following table:

Minerva's boilers.	Without retarders.	With retarders.
Heat transmitted per square foot of heating surface per hour, B. T. U.	9,560	10,220
Heat utilized per boiler per minute, B. T. U.	368,000	393,000
Air pressure in stokeholds, inches of water	0.81	0.65
Rise of temperature of flue gases, degrees Fahrenheit	761	634
Coal used per boiler per hour, pounds	2,462	2,363
Water evaporated per boiler per hour, pounds	19,530	20,890
Boiler efficiency, per cent.	61.4	68.4

With the retarders the efficiency of the cylindrical boiler is the same as that of the Belleville boiler, and inasmuch as retarders are simple, inexpensive, and in no way difficult to use, it follows that the "economical" argument in favor of the Belleville boiler has no weight or substance whatever. By-and-bye we shall consider the performance of the *Saxonia* boilers and engines, but for the present we shall center our attention on the two men-of-war.

(4) *The Scotch Boiler is More Liable to Break Down than the Belleville Boiler.* The report conclusively and effectually refutes this proposition. It was already known that the *Hyacinth* could not keep at sea until her bunkers were emptied on the run out to Gibraltar, because her boilers leaked so much that her supply of fresh feed water could not be kept up. What happened on the run home is best told in the words of the committee. The italics are ours.

"The *Hyacinth* experienced great trouble from loss of water during the whole of the run home. The 40 tons of ordinary reserve water was finished by 5·15 A. M. on the 20th, although her evaporators had been working practically all the time. In addition to this, it was reported at the end of the run that she had used 58 tons from the special reserve tanks. It would therefore appear that, as these tanks were especially fitted for this voyage and formed no part of the ordinary equipment of the ship, the *Hyacinth could not under normal conditions have completed the full-power run home at all unless she had used salt water makeup*, for her evaporators were pushed to their full output throughout. The total feed water lost was 329 tons, or 16.7 tons per 1,000 horse-power per twenty-four hours.

"At 6·10 P. M. on the 20th, that is, when the *Hyacinth* was within four hours of Spithead, a tube burst in No. 10 boiler. A stoker was slightly injured by steam and hot coal while closing a fire door. The fires in this boiler were drawn and the boiler shut off. The damaged element was afterwards brought ashore and cut up for examination. No. 10 boiler is a wing boiler, and the burst tube was the fifth from the bottom in the outer row of the wing element. The rent was on the side away from the

casing, the side which would naturally receive most heat. The tube had clearly been red hot, the softened steel stretching out under the steam pressure into a large swelling which finally burst, the actual rent being about 8 inches long and 3 inches wide at the center. The edges of the rent were drawn down quite thin and sharp, and there was every indication that the steel was of excellent quality. The lower tubes of the element, up to about the normal water level, as indicated by the gauge glass, were coated internally with a thin lime deposit. The upper tubes, above the burst one, had not this deposit; they were bulged in places and reduced in thickness by stretching and wasting away. It was plainly only a matter of accident which tube split first out of several.

"An examination of the boiler by the representatives of the Committee on board immediately after the accident showed that both the lead plugs were gone in this element, and that the lower plugs were gone in the two wing elements on the opposite side of the boiler, and the lower plug out of the element next the one with the burst tube. The gauge glasses and their connections were found not to be choked in any way. The hole in the nipple of the burst element was found to be clear, and the amount of loose scale in the feed collector was small, and not nearly enough to suggest any temporary choking of the hole in the nipple from the cause. As far as could be seen, the other elements of this boiler were uninjured.

"The engine-room register for 20th of July contains the following entry, the page containing it being signed by the Staff Engineer:

"'Tube burst in No. 10 boiler, fifth row up of ninth element; water in gauge glass, ¾ glass at time. Opened safety valves, shut off boiler, and drew fires as soon as possible.'

"The fact that one element was, under these circumstances, practically dry—so empty of water that several tubes in it could become red hot—and that the very element to which the gauge glass was attached—emphasizes most strongly the fact pointed out by the Committee in their Interim Report, that the water gauge indications in the Belleville boiler are entirely untrustworthy. This untrustworthiness is a most serious defect, and

may even become a serious danger in the working of boilers of this type. It must be remembered that the boilers were only being worked at about 25 pounds of coal per square foot of grate—a far lower figure than in the *Minerva*—and that the conditions were in no way different from what they must always be when the ship is driven at full speed.

"The lead plugs proved to be no safeguard whatever against accident in this case.

"In another element of the same boiler, when it was overhauled at Portsmouth after the accident, a loose handhole door was found in the lower junction box, in such a position as to act as a non-return valve on the nipple, the stud of the door forming the stem of the valve in the bore of the nipple. The element where this obstruction existed was examined in place but showed no damage. It seems, therefore, that the ordinary variations of firing in a Belleville boiler may cause much more serious changes in circulation than even an obstruction so obvious that, if it had occurred in the burst element, it would certainly have been put down as the cause of the accident.

"The amount of makeup water required by the *Minerva* was quite moderate. The 40 tons was, by an oversight, exceeded, and 65 tons were used from the reserve tanks, only 19 tons being made by the evaporators. The feed water lost was 85 tons, or $\frac{4}{66}$ tons per 1,000 horsepower per twenty-four hours.

"At the higher powers both vessels worked with closed stokeholds. The *Hyacinth* had generally an air pressure of about 0.5 inch of water, and the *Minerva's* stokehold pressures—as mentioned below—vary from 0.67 inch to 1.5 inches."

We think that our readers will agree with us that this evidence is conclusive. It may, perhaps, be urged that Belleville boilers in other ships have done better than those in the *Hyacinth*. With that we have nothing to do. We refuse to go outside the limits of the facts with which the Committee have to do, and it ought to be borne in mind that this report is the only full and unbiased report that has been made public concerning the relative performance of Belleville and Scotch boilers, and in that way possesses a very special value.

Power	At about 2,000 H.P.						At about 5				
Name of ship	*Minerva.*		*Hyacinth.*				*Minerva.*				
Duration of trials, hours	25		18		6½		24		12		
Closed exhaust or open exhaust in use	Open.		Closed.		Open.		Open.		Closed.		
Steam jackets in use	All.		L.P.		L.P.		All.		L.P.		
Total water used by machinery per hour	38,992		39,082		39,572		78,113		85,445		
Mean steam pressure by gauge on H.P. valve chest, lbs.	80		109		110		138		167		
Which engine	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	S
Average revolutions per minute, main engines	82.9	84	101.4	101.7	100.6	99	110.4	111	138	138.7	1
I.H.P., high-pressure cylinder	432	380	323	279	331	279	776	689	765	718	
intermediate-pressure cylinder	352	334	246	259	252	248	874	835	638	696	
forward low-pressure cylinder	320	324	253	247	241	209	976	1,005	579	557	
aft low-pressure cylinder	...	...	237	235	211	196	...	...	550	522	
Total average I.H.P. per set	1,104	1,038	1,059	1,020	1,035	932	2,626	2,529	2,532	2,493	2
Collective average I.H.P.	2,142		2,079		1,967		5,155		5,025		
Average I.H.P. for period of boiler trial	2,142		2,049				5,155				
Corresponding pressure on L.P. piston	15.2		18.8		18.1		27.6		33.4		
Steam used by main engines per I.H.P. per hour	15.9		18.45		16.86		13.40		16.78		
auxiliary engines per I.H.P. per hour	2.02				2.91		1.33				
jackets per I.H.P. per hour	0.28		0.35		0.35		0.42		0.22		
Total steam used by engines per I.H.P. per hour	18.20		18.80		20.12		15.15		17		
Water supplied for makeup per I.H.P. per hour	0.20		0.51		0.51		0.28		0.26		
Total water used by machinery per I.H.P. per hour	18.40		19.31		20.63		15.43		17.26		
Thermal efficiency of engines, per cent	14.4		...		13.5		16.7		...		
Thermal efficiency of engines, including auxiliary engines, based on I.H.P. of main engines	12.8		12.3		11.5		15.3		13.6		
Efficiency ratio	62.7		...		54		65		...		
Coal used per I.H.P., pounds per hour	2.15		2.03				1.74		...		
Makeup water per 1,000 I.H.P., tons per 24 hours	2.09		5.48		5.48		3		2.87		

* First intermediate cylinder. † Second intermediate cylinder..

OF RESULTS OF ENGINE TRIALS.

At about 5,000 H.P.							At about 8,000 H.P.						Full power. *Hyacinth.*		Retarders in 4 boilers. *Minerva.*		At about 9,000 H.P. *Saxonia.*	
va.	*Hyacinth.*						*Minerva.*		*Hyacinth.*									
4	12		6		6		9		8		4		8		8¼		13	
.	Closed. L.P.		Closed. None.		Open. None.		Open. All.		Closed. None.		Open. None.		Open. None.		Open. All.		Closed. None.	
3	85,445		83,006		85,934		153,389		146,286		136,551		185,605		81,908		130,250	
	167		167		167		136		194		192		220		128		192	
ort.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.	Star.	Port.
111	138	138.7	136.6	137.2	135.9	135.4	128.4	128.7	159	159.7	157.3	157.4	169.5	171.9	108.3	108.1	78	77.5
689	765	718	772	720	815	744	1,345	1,200	1,210	1,083	1,194	1,083	1,445	1,349	786	685	985	981
835	638	696	644	695	710	749	1,384	1,314	1,086	1,259	1,124	1,259	1,364	1,588	891	802	1,158*	1,067*
005	579	557	556	541	513	477	1,423	1,466	933	934	810	787	1,111	1,133	778	829	1,202†	1,086†
..	550	522	540	507	493	456	...	...	871	901	765	773	1,092	1,098	...	...	1,420	1,200
529	2,532	2,493	2,512	2,463	2,531	2,426	4,152	3,980	4,100	4,177	3,893	3,902	5,012	5,168	2,455	2,316	4,765	4,334
5	5,025		4,975		4,957		8,132		8,277		7,795		10,180		4,771		9,099	
5			4,995				8,132				8,116		10,180		4,771		9,099	
	33.4		33.4		33.6		37.4		47.8		45		44.8		26.1		39.	
0	} 16.78		16.68 {		15.56		16.30		} 16.88 {		15.08		15.42		14.85		13.47	
3					1.78		2.20				1.65		1.72		1.73		0.86	
2	0.22		...		...		0.36		...		...		...		0.59		...	
5	17		16.68		17.34		18.86		16.88‡		16.73‡		17.14‡		17.17		14.33	
8	0.26		0.26		0.26		0.35		0.51		0.51		0.45		0.34		0.26	
3	17.26		16.94		17.60		19.21		17.39		17.24		17.59		17.51		14.59	
	...		...		14.7		13.9		...		15.1		14.6		15		17.2	
	13.6		13.9		13.3		12.3		13.4		13.6		13.2		13.5		16.1	
	...		...		54		56.2		...		53.4		50.9		59.2		62.8	
4	...		1.84		...		2.42		1.84 for 11 hours.				2.11		1.98		1.29	
	2.87		2.87		2.87		3.73		5.46		5.46		4.84		3.68		2.76	

ediate cylinder.. ‡ After deducting wetness in steam.

We now come to a different branch of the subject. We have so far only the performance of the boilers to consider, but the Committee have luckily not confined their researches to boilers. The propelling plant of our cruisers and warships must be dealt with as a whole. Of late years very high pressures, and short-stroke, quick-running engines have been introduced into the Navy We have repeatedly said that we hold it to be a mistake to think that these conditions of service conduce to economy. It may, indeed, be urged that they are necessary in order to keep down weight. We have already disposed of this contention. Let us see what the report has to say on the subject of economy.

5. *Owing to Higher Pressures and Higher Speeds the New Propelling Plant is, as a Whole, More Economically Efficient Than the Old Plant.* We have seen that the boilers, at all events, are not better. If there is really a gain it must be in the engines. The Committee tell us that engines of the *Minerva* type can, practically, be made as economical in working as first-class engines in merchant steamers, but this is not true of naval engines of the short-stroke and quick-revolution type, even when working with a much higher pressure of steam. Here it is necessary to add that the remarks of the committee are based entirely on the indicated power of the engines, and have nothing to do with their net power or that conveyed to the propeller. It goes, however, without saying, that short-stroke, high-speed engines must waste much more power in friction, and that vague and unappreciated source of waste of power involved in the rapid reciprocation of heavy weights, than the slower-running machinery of such ships as the *Minerva*. It will be remembered that the *Minerva* is a faster ship than the *Hyacinth*, and some difficulty has been found in explaining the fact. If it were possible to ascertain the net as well as the indicated powers of the machinery of the two ships, we believe that the solution of the problem would at once lie before us. As to the actual thermal efficiency of the two engines, the *Minerva* comes first with 16.7 per cent., that of the *Hyacinth* engines being 15.1 per cent. The folding table which we have condensed from the report, sets forth the particulars in detail.

TABLE III.—BOILER TRIALS.—ABSTRACT FROM REPORT OF THE COMMITTEE.

.....	At about 2,000 H.P.		At about 5,000 H.P.		At about 8,000 H.P.		Full power. *Hyacinth.*	Retarders in four boilers. *Minerva.*	At about 9,000 H.P. *Saxonia.*
	Minerva.	*Hyacinth.*	*Minerva.*	*Hyacinth.*	*Minerva.*	*Hyacinth.*			
Date of trial, 1901	Jan. 14, 15	May 30, 31	Mar. 8, 9	June 6, 7	Mar. 15	June 25	June 18	May 29	Feb. 5, 6
Duration of trial, hours	25	24½	24	24	9	11	8	8½	13
In use during the trial, number of boilers	4	6	8	12	8	18 for 1½ h. 17 for 9½ h.	18	4	9
area fire grate, sq. ft.	325	264	649	528	649	791—747	791	325	570
heat. surf., sq. ft.	9,232	8,142	18,464	16,284	18,464	24,426 23,069	24,426	9,232	25,803
Analysis of coal, per cent.:									
Carbon	85.60	...	86.95	...	...	...	...	...	85.28
Hydrogen	3.96	...	4.02	...	...	...	...	...	4.40
Moisture	1.18	0.82	0.86	0.76	1.10	0.92	0.91	0.82	0.58
Ash	5.28	4.18	4.32	3.41	4.30	4.16	5.01	4.18	5.96
Oxygen and other matters	3.98	...	3.85	...	...	...	...	...	3.78
Calorific value of coal as fired, B. T. U., per lb.	14,267	14,679	14,697	14,805	14,686	14,578	14,611	14,612	14,475
Carbon value of coal as fired	0.98	1.01	1.01	1.02	1.01	1	1	1	1
Analysis of flue gases, by weight, per cent.:									
Carbonic acid	13.20	9.98	12.56	14.80	13.45	17.10	...	...	11.94
Carbonic oxide	Nil.	0.21	0.45	0.24	0.29	0.47	...	...	0.57
Oxygen	10.50	9.38	11.63	9 55	10.76	7.40	...	...	11.55
Nitrogen (by difference)	76.30	80.43	75.36	75.41	75.50	75.03	...	...	75.94
Average temperature of flue gases, degrees F.	637	544	640	621	804	703	780	699	396
Weight of air used per lb. coal fired, lbs.	22.9	20.5	23.3	20.2	21.8	17	...	...	23.4
flue gases per minute, lbs.	1,864	1,483	3,630	3,103	7,423	4,082	...	...	4,800
Air temperature on deck, degrees F.	48	55	48	58	43	60	55	65	50
Difference between the air temperature and temperature of flue gases, degrees F.	589	489	592	563	761	643	725	634	346
Mean air pressure in closed stokehold, inches of water	Nil.	Nil.	Nil.	Nil.	0.81	Nil.	Nil.	0.65	...
Mean air pressure in closed ash pit, inches of water	...	...	...	...	...	...	...	...	1.53
Mean vacuum at base funnel, inches of water.	0.36	0.36	0.50	0.39	0.39	0.43	0.39	0.32	0.58
Average feed water pumped into the boilers per hour, lbs.	39,410	40,260	79,560	86,300	156,220	147,190	190,210	83,550	132,601
Average feed water pumped into the boilers per minute, pounds	657	671	1,326	1,438	2,604	2,453	3,170	1,392	2,210
Temperature of feed water on entering the									

per hour, lbs.	39,410	40,260	79,560	86,300	156,220	147,190	190,210	83,550	132,601
Average feed water pumped into the boilers per minute, pounds	657	671	1,326	1,438	2,604	2,453	3,170	1,392	2,210
Temperature of feed water on entering the									

TABLE IV.—BOILER TRIALS.—ABSTRACT FROM THE REPORT OF THE COMMITTEE.

.....	At about 2,000 H.P.		At about 5,000 H.P.		At about 9,000 H.P.
	Minerva.	*Hyacinth.*	*Minerva.*	*Hyacinth.*	*Saxonia.*
Pressure boiler safety valves are set at, pounds per square inch	155	320	155	320	210
Mean steam pressure in boilers by gauge, pounds per square inch	110	195	144	199	199
Corresponding temperature of saturation, degrees Fahrenheit	344	386	363	387	387
Observed temperature of steam in the run of steam piping, degrees Fahrenheit	338	372	360	376	Not taken.
Average wetness of steam, per cent	0.00	0.32	0.00	0.40	"
Heat lost by incomplete combustion per minute, B. T. U.	Nil.	11,800	68,700	32,000	126,700
carried away by flue gases	260,200	171,900	509,300	430,000	238,700
used in warming air through heater	...	...	...	...	108,400
corresponding to formation of steam in boilers per minute, B. T. U.	761,000	785,400	1,496,000	1,631,000	2,329,000
expended on priming water, per minute, B. T. U.	...	800	...	1,800	...
Balance lost by radiation and otherwise unaccounted for (by difference), B. T. U.	71,800	47,100	130,000	177,200	27,200
Total heat corresponding to perfect combustion of coal per minute	1,093,000	1,017,000	204,000	2,272,000	2,830,000
Thermal efficiency of boiler, per cent	69.7	77.2	68.0	71.8	82.3
Actual evaporation per pound of coal as fired, pounds	8.56	9.65	8.84	9.33	11.30
per square foot of heating surface per hour, pounds	4.26	4.94	4.32	5.30	5.14
Equivalent evaporation per pound of coal from and at 212 degrees, Fahrenheit, pounds	10.26	11.46	10.33	11	12.33
Weight of coal burnt per square foot of grate surface per hour, pounds	14.2	15.8	13.9	17.4	20.6
Heat transmitted per square foot of heating surface, B. T. U.	4,946	5,794	4,861	6,016	5,416

So far we have confined our attention to the performance of the *Hyacinth* and the *Minerva*. We have now to consider the results obtained with the Cunard Atlantic steamer *Saxonia*. These possess an interest quite apart from the controversy about Belleville and Scotch boilers. In a general way engineers and shipowners know pretty well what marine engines and boilers can and cannot do; but it is very rarely indeed that any careful or exhaustive inquiry is made to obtain precise information as to the effect of any particular system of working or special appliances. The world owes something to the Committee for pushing its inquiries outside the Navy.

The first point claiming attention is that the quadruple-expansion engines of the *Saxonia*, working with steam of 220 pounds pressure, are not more economical, or, to be strictly accurate, are not appreciably or in effect commercially more economical, than the triple-expansion engines of the *Minerva*. The Committee say: "On the whole, it would appear that engines of the *Minerva* type can practically be made as economical in working as first-class engines in merchant steamers." From this it follows that there is nothing to be gained by the use of steam of 220 pounds and quadruple expansion as compared with steam of 150 pounds and triple expansion. This being so, there is evidently much to be gained by adhering to the lower pressure and the simpler type, because, each increase of pressure means, other things being equal, a great augmentation in weight. A boiler to carry 155 pounds may obviously be much lighter than one carrying 220 pounds. Indeed, the figures given in the report are tolerably conclusive that no attempt has been made to keep down the weight of the *Saxonia's* machinery or boilers. But the *Saxonia's* most economical power is 9,000 horses. The *Minerva* can get up, when pressed, to about the same; but her best fuel results are obtained when her engines are indicating about half power, or, say, 4,500 horses. No doubt the *Saxonia* could be worked up to very much more than 9,000 indicated horse-power, but it is more than probable that her economical efficiency would then fall off, as does that of the *Minerva*. It seems, indeed, that the performance of the two sets of engines—those

of the *Saxonia* and the *Minerva*—may be strictly comparable all through a somewhat wide range, always bearing in mind that the engines of the *Saxonia* are much larger and more powerful than those of the cruiser. If we take the facts in consideration, it will also be seen that the *Saxonia's* engines are not so much heavier for their power than those of the *Minerva*. For ordinary cruising purposes there is not any wide difference. It is only when the cruiser is driven that her engines appear to be light. The same result would be obtained, or nearly the same result, if the *Saxonia* were forced up to 17,000 or 18,000 indicated horsepower.

So far, then, as this report goes, there is no reason to believe that quadruple expansion is better than triple expansion. In writing thus we deem it necessary once more to guard ourselves against being misunderstood. We have already been told that we have condemned the water-tube boiler in our first remarks on this report. But, as a matter of fact, we have expressed no opinion whatever on the subject. We have carefully confined ourselves to telling our readers the story of the Boiler Committee, and drawing the only possible deductions from that story. In like manner we do not now express any personal opinion concerning the relative merits of triple and quadruple expansion. We content ourselves with calling attention to the fact that the Boiler Committee hold that the engines of the *Minerva* are as economical, at or about 4,500 indicated horsepower, as are those of the *Saxonia* at 9,000 indicated horsepower. There is no reason whatever, that we can see, why, taking weight for weight, we shall not consider that 9,000 indicated horsepower for the *Saxonia* is the precise analogue of half power for the *Minerva*. The *Saxonia* is, no doubt, more economical than the *Minerva*, but the Committee say, "The difference between the *Saxonia* and the *Minerva* lies altogether in the boilers." It will be remembered that these boilers are "Howdenized"—that is to say, they are fitted with a great number of tubes in the uptake, by means of which the air supplying the furnaces is heated. We have over and over again urged on the Admiralty a trial of the system which has been applied to boilers generating some mil-

lions of horsepower, but hitherto without success. Now it is to this system that the economy of the boilers of the *Saxonia* is largely due; and the fact must be emphasized and insisted upon, as far as lies in our power. We have not thought it necessary to reproduce that portion of the report which details the elaborate methods adopted to obtain accurate information. It will be enough to say here concerning one point of importance, namely, the quantity of air admitted to the furnaces, that the flue gases were collected and analyzed. We shall return to this fact presently. Meanwhile let us see what the report has to say about the efficiency of the boilers:

"In comparing the *Saxonia* with the cruiser, it has to be remembered that the machinery of a merchant steamer is designed to work more economically at one particular power—in this case 9,000 to 10,000 horsepower—whereas the engines of the cruiser have to give reasonably economical results at any power varying from 25 per cent. to 75 per cent. of their full power. Even keeping this in mind, however, the difference between the results—due to various causes—obtained in the *Saxonia* and in the cruiser are remarkable. The boiler efficiency of the former reaches the exceptional figure of 82.3 per cent. The boilers are, of course, large for their work, the rate of combustion being 20.6 pounds per square foot of grate, and the heat transmission 5,416 thermal units per square foot of heating surface. But this does not differ very much from the rate of transmission in the *Minerva* and the *Hyacinth* at 2,000 and 5,000 horsepower with the number of boilers actually in use at the trials, when the highest attained efficiencies were 71.8 and 77.2 per cent. The evaporation "from and at" in the *Saxonia* is, of course, correspondingly high, being as much as 12.3 pounds of coal."

The Committee express regret that the trial of the *Saxonia* only lasted thirteen hours, the duration of the run from Liverpool to Queenstown, and they suggest that even better results would have been obtained when the stoking was improved. It was never equal to that on board the cruiser. After referring to the temperature in the uptakes, 396 degrees Fahrenheit, subsequent to passing through the Howden heater, the report goes on:

"This corresponds to the utilization of nearly 4 per cent. of the whole heat of combustion, which would otherwise have been wasted up the funnel. But, apart from this, the heating surface was exceptionally efficient, as the temperature of the flue gases was only 491 degrees Fahrenheit before they reached the heater, and this figure compares very favorably with the corresponding figures in line 17 of the table. The number and dimensions of the tubes, which were all fitted with retarders, will be found, for comparison with those of the *Minerva*, in Table I, pages 460, 461.

As to the completeness of the combustion in the furnaces, it will be seen that there is not much to choose between the three vessels. On the 2,000-horsepower trial of the *Minerva* no carbonic oxide was found in the gases, and in the similar trial of the *Hyacinth* very little, but in all the other runs the amount was considerable, being largest of all in the *Saxonia*. The air used per pound of coal was least on the *Hyacinth's* 8,000-horsepower trial, but the proportionate loss due to incomplete combustion was not quite so great as in the *Minerva* at 5,000 horsepower, although the air used in the latter was 23.3 pounds instead of 17 pounds per pound of coal. The maximum loss—about 4 per cent.—was in the *Saxonia*, with 23.4 pounds per pound. In connection with these figures it is, however, to be noted that, although the analyses given represent with great accuracy the actual composition of the samples of gas collected, it is in the nature of things impossible to ensure that the gases collected from a particular position in the funnel shall really be a true average sample of the gases passing up the whole area of that funnel, still less that they shall exactly represent the true average constitution of the gases in other funnels. The figures from which the thermal efficiency of the boilers is calculated are, of course, not affected by the analyses of the gases, but the accuracy of those dealing with the heat lost by incomplete combustion, carried away by flue gases, &c., depends entirely on the extent to which the samples collected correspond to the actual average of the whole gases. The results given are no doubt substantially accurate, but there are several indications that the actual average weight of air per pound of coal on the 8,000-

horsepower trial of the *Minerva* must have been somewhat greater than that calculated from the composition of the gases, and that in the *Saxonia* the air must have been somewhat less than calculated, and probably also the average amount of carbonic oxide was less than in the collected samples.

The table which we give is No. XXV in the report. We have slightly condensed it. We may add here that the mean temperature at the base of the funnel of the *Saxonia* was 393 degrees Fahrenheit; in the smoke box, 487 degrees Fahrenheit, while that of steam of 220 pounds is about 395 degrees Fahrenheit, so that the gases went away at about the same temperature as the boiler.

The following extracts give information on certain matters of detail which are of interest:

"The *Minerva* used the steam jackets on all her channel trials. The *Hyacinth* used low-pressure jackets at 2,000 and 5,000 horsepower, but not at 8,000 nor 10,000 horsepower. The *Saxonia* has jackets on the second intermediate-pressure and low-pressure cylinders, but they were not used on this trial.

The revolutions of the *Hyacinth's* engines average about 23 per cent. higher than those of the *Minerva* at each power, and their mean pressure reduced to the area of the low-pressure piston or pistons, exceeds that of the *Minerva* in practically the same proportion. These figures, of course, correspond to the alteration in engine type, in the direction of shorter strokes, larger number of revolutions and higher pressures, which has been in progress in the Navy for some years past. The piston speeds, at full power, in the two ships are practically equal, about 855 feet per minute. The equivalent mean pressure in the *Saxonia* is only about equal to that in the *Minerva* at full power, 39.0 pounds per square inch, although her initial pressure is higher. Her piston speed is considerably smaller, namely, 702 feet per minute.

"As to engine economy, comparing in the first instance the two cruisers only, it will be seen that at the two lowest powers the *Minerva* uses considerably less steam per horsepower hour for all purposes than the *Hyacinth*. At 2,000 horsepower the comparative figures are 18.20 and 18.80, and at 5,000 horsepower,

15.15 and 16.68. The figures correspond to the actual running of the ships as fitted, the closed exhaust being in use in the *Hyacinth*. At 2,000 horsepower the extra steam used, owing to the employment of the open exhaust in the *Hyacinth*, was found to be 7 per cent., and at 5,000 horsepower, 4 per cent., and it would seem reasonable to expect that a corresponding difference would be found in the case of the *Minerva* if her auxiliary engines were fitted in the same way.

"As already mentioned, the steam used for the jackets in the *Minerva's* 2,000-horsepower trial is an estimated figure, obtained from other trials, but the comparison above made remains practically unaltered if the figures for the jackets be omitted altogether.

"On the 5,000-horsepower trial of the *Hyacinth* the disuse of jackets seemed to be an advantage, reducing the steam consumption from 17 pounds to 16.68 pounds, or, practically, by just the amount of steam used in the jackets. They were, therefore, not used at the higher powers. No similar comparison was made with the *Minerva*, but on the run out to Gibraltar, at 7,000 horsepower, it was considered best to work without any jackets."

It may, perhaps, be worth while to explain that the auxiliary engines, not being compound, discharge their steam at a considerable pressure into the condenser. This is working "with open exhaust." They are, however, so fitted that they can discharge into the low-pressure receiver, and thus work compound with the low-pressure main engines. This is "working with a closed exhaust," and is, of course, conducive to economy.

There remains for consideration the important question of the relative weight and cubic space occupied by the propelling plant of the ships. The retention or rejection of the Scotch boiler and *Minerva* type of engines turns largely on this. The Committee have dealt with it very fully, and yet much more might be said. We shall, however, conclude what we have to say about the following extract condensed from its pages:

"The actual thermal efficiency of the engines, that is, the ratio of heat turned into work to heat received, is naturally more correctly proportional to the economy of the engine than the steam consumption is, as it takes into account the different amounts of

heat received per pound of steam in different cases, but the results stated by the two methods are not practically different. The *Saxonia* comes first with 17.2 per cent., then the *Minerva* with 16.7 per cent., and the best performance of the *Hyacinth* is 15.1 per cent. When the auxiliaries are taken into account these figures are modified, but retain the same general proportions.

"Comparing the ratio of the actual efficiency of the engine to the best possible efficiency, we find how far each engine approaches the highest economy which can be theoretically attained by an engine of its own type working with its own steam pressure. This discounts the effect of different initial pressures in comparing different engines. Compared in this fashion, the *Minerva* reaches 65 per cent., the *Saxonia* 62.8 per cent., and the *Hyacinth* 54 per cent. A comparison of the figures illustrates the fact already well proved, that as the theoretical efficiency of a machine is increased, so also are the difficulties of practically obtaining it. The *Minerva* can obtain 65 per cent. of a possible 25.7 per cent. as easily as the *Hyacinth* can obtain 53.4 per cent. of a possible 28.3 per cent.

"As to the pressure on the various pistons reduced to corresponding pressures on the area of the low-pressure piston or pistons, and added together.—The *Saxonia* at 9,000 horsepower, and the *Minerva* at full power, do not differ greatly—39.0 pounds and 37.4 pounds—although the former vessel works at a higher boiler pressure. The *Hyacinth*, of course, has a much higher reduced pressure—54.8 pounds at full power and 47.8 pounds at 8,000 horsepower, this being a part of the intention in altering the engine design—in order to get machinery which would occupy less space. The actual net space occupied by the main and auxiliary engines and evaporating plant in the *Hyacinth* is 28,200 cubic feet, and in the *Minerva* 29,240 cubic feet. Taking these figures in connection with the maximum horsepower measured on any of the Committee's trials over a period of several hours—10,180 and 8,657 horsepower* respectively—they amount to 2.8 and 3.4 cubic feet per maximum horsepower in the *Hyacinth* and *Minerva* respectively. The weights of the engines complete

*On the contractors' full-power trial of the *Minerva* in 1896, 9,900 horsepower was developed for four hours, 9,600 being the specified figure.

with shafting, propellers, and spare gear, including evaporating and electric-light plants, are given as 378.4 and 364.8 tons, which gives 26 9 and 23.7 horsepower per ton respectively for the two vessels.

"The weight of the boilers, with funnels and water, and the whole of the boiler-room weights generally, are 453.8 and 557.4 tons in the *Hyacinth* and *Minerva* respectively. Worked out on the same horsepower as in the last paragraph, the figures come to 22.4 and 15.5 horsepower per ton of boiler weights in the two vessels. It must be noted, however, that figures such as these may be very misleading; the saving in weight of machinery which they indicate may easily be more than counterbalanced by additional necessary weight in coal and water. It will be seen by figures given further on that, taking machinery, boilers, coal and water together, there is very little difference between the two ships, and that the difference on the long voyage was in favor of the *Minerva*.

"As to the combined performance of engines and boilers, as represented by the coal consumption per horsepower.—At 2,000 and 8,000 horsepower the *Hyacinth* has the advantage in this respect, while at 5,000 horsepower the *Minerva* shows best. The *Hyacinth's* consumption at different powers is much more uniform than that of the *Minerva*, the latter ship being markedly more economical at medium powers than at either end of the scale. It has to be remembered, however, that the *Minerva* has seen much more service than the *Hyacinth*, and that in general it has been found that coal economy falls off as boilers and machinery become older. In this connection a comparison of the results of the Committee's trials in respect to coal consumption, with the contractors' trials of the same vessels, is instructive. The comparative figures are given in a table on page 484.

"There was no contractors' trial of the *Minerva* at 2,000 horsepower, but comparing the 1896 trials at 5,000 and 8,000 horsepower with those of 1901, it will be seen that after four years' active service the coal consumption has only increased on the average 8.5 per cent. Comparing the corresponding two trials of the *Hyacinth*, the difference is 21 per cent., although the ship

had not seen any service except a few special trials, and had been specially prepared for the Committee's trials by thorough overhauls and trials at Devonport. At full power the difference is still greater, viz: 32 per cent. The Committee do not think that this falling off was an accident of these trials, or even that it is peculiar to the *Hyacinth*. It occurred in a still more marked degree on the run to Gibraltar and back, and it is clearly noticeable in the records of the Belleville boilered vessels which have been submitted to the Committee.

"The coal consumption of the *Saxonia* works out to 1.29 pounds per horsepower hour, a figure in itself most satisfactory, but one which can hardly be expected to be reached with machinery built under so many necessary limitations of space and weight, and to meet such varied conditions — some of which have been pointed out above — as machinery in a war vessel.

Finally we may say that the report contains much detailed matter of interest and a sufficient number of examples of indicator diagrams taken from the engines of the three ships. These present no peculiarities; those of the *Hyacinth*, however, might, perhaps, be slightly improved by small alterations in the setting of the valves. All the diagrams are about as good as can be obtained in the ordinary course at sea.

HYACINTH.

Date of contractors' trial.	Duration in hours.	H.P.	Coal per H.P. per hour.	Date of Committee's trial.	Duration in hours.	H.P.	Coal per H.P. per hour.	Ratio.
1899.				1901.				
6 and 7 November	30	2,146	1.72	30 & 31 May..	24½	2,049	2.03	1.18
...	...	...	...	5 & 6 June.....	24	4,995	1.84	...
9 and 10 November.....	30	7,678	1.48	25 June.....	11	8,116	1.84	1.24
4 December	8	10,447	1.59	18 June.....	8	10,180	2.11	1.32

*MINERVA**.

1896.				1901.				
...	...	...	...	14 & 15 Jan	25	2,142	2.15	...
29 and 30 September....	30	4,919	1.71	8 & 9 March ..	24	5,155	1.74	1.02
24 September.....	8	8,218	2.10	15 March	9	8,132	2.42	1.15

* It is interesting to note that, on the Committee's trials in 1901, the *Minerva* did considerably better than on her special trials against the *Highflyer* in 1900, and also that the *Hyacinth's* performances as to coal were very much better than those of the *Highflyer* throughout the whole range of power. (See "Memorandum respecting Water-Tube Boilers in H. M. Ships," presented to Parliament in 1900.)

A DEFENSE OF THE NICLAUSSE BOILER.

By J. & A. Niclausse.

In the February number of the JOURNAL for the current year was published an article by Marine Oberbaurath Kohn Von Jaski on "The Water-Tube Boiler Question in the German Navy." This article originally appeared in the "Marine Rundschau," May, 1901.

The Council of the Society have lately received the following letter and comments on certain parts of the article from the firm of J. & A. Niclausse, Paris, France:

"Gentlemen: In the JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, February, 1902, we read a translation of an article published in the "Marine Rundschau," May, 1901, under the signature of Mr. Kohn Von Jaski.

"This article, containing some unfavorable and inexact statements concerning the boilers manufactured by us, prompted us to address to its author and to the editor of the "Marine Rundschau" a note correcting these statements, and a request that this note should be published. This request was granted, and the note appeared in the "Marine Rundschau," in September, 1901.

"We send you this discussion, in which the statements are the same as in that published in the last-mentioned number of the "Rundschau," and we do not doubt that you will publish in the next number of your JOURNAL, as is no more than just to us, the remarks that we have made, in order to correct the inexact statements of a person who has certainly been misinformed.

"Accept, gentlemen, the assurance, etc."

In summing up concerning the Niclausse boiler, Mr. Von Jaski declares that the experiences in Germany with that boiler up to date are unfavorable, and he quotes in support of his assertion

the abnormal length of time taken for the trials of the *Freya* and the *Gazelle*. In fact, these trials did begin in 1898, and it was not until April, 1901, that these cruisers were ready to go in commission with boilers serviceable for a man-of-war.

We desire to show that the Niclausse boilers were not responsible for this extraordinary delay.

The principal cause of the delay from the end of 1898 to October, 1900, was due to the necessity of carrying out an order which required all the malleable iron lanterns to be replaced by new ones of seamless steel.

We have been informed by the Chantier Germania, the builders of the cruisers, that after the first trials in 1898, which were very satisfactory, the Imperial German Department of the Navy directed the exchange of lanterns above mentioned, because, in taking the boilers to pieces, as it is customary to do after first trials, some of the original lanterns were broken (9 in 3,180, about 0.3 per cent).

This breakage we have since learned was due to the fact that, notwithstanding the express directions we had given to use our special and simple tools in setting the tubes, the tubes had been driven into their seatings with hammers, thus producing an abnormal strain on the metal of the lanterns.

Had the German Navy used our tools as directed, as is done in all other navies, the results would have been as satisfactory as are obtained everywhere else. As proof of this satisfaction we cite the following:

1. In Russia, after the trials of the gunboat *Khrabry*, 3,000 I.H.P., which has been in commission for five successive years, the Niclausse boilers were installed in the *Variag*, 20,000 I.H.P., the *Retvisan*, 16,000 I.H.P., and the *Ocean*, 3,000 I.H.P.

2. In England, after the trials of the gunboat *Seagull*, 3,000 I.H.P., the Niclausse boilers were placed in the *Fantôme*, 1,400 I.H.P., the *Suffolk*, 22,000 I.H.P., and the *Berwick*, 22,000 I.H.P.

3. In Spain, after the trials of the *Cristobal Colon*, 14,000 I.H.P., built in Italy, the Royal Marine Department employed the Niclausse boiler in the battleship *Pelayo* of 9,000 I.H.P.

4. In Italy, they have begun successively, the *Francesco Ferru-*

cio, 14,000 I.H.P., the *Garibaldi*, 14,000 I.H.P., and the *Regina Margherita*, 19,000 I.H.P.

5. In the United States, the Niclausse boilers are placed in the *Maine*, 16,000 I.H.P., the *Connecticut* (*Nevada*), 3,000 I.H.P., the *Colorado*, 23,000 I.H.P., and the *Pennsylvania*, 23,000 I.H.P.

6. In Japan, the cruiser *Yaeyama*, 6,000 I.H.P.

7. In Turkey, in the battleship *Messudieh*, 11,000 I.H.P.

8. In France, after the trials of the *Elan*, 500 I.H.P., and of the *Friant*, 9,000 I.H.P., they were placed in the gunboats *Zelée* and *Decidée*, 1,000 I.H.P. each, the torpedo gunboat, *Temeraire*, 1,500 I.H.P., the cruiser *Fleurus*, 4,000 I.H.P., the cruiser *Davout*, 9,000 I.H.P., the armored cruiser, *Kleber*, 18,000 I.H.P.; the following armored cruisers, *Gueydon*, 20,200 I.H.P., *Condé*, 20,500 I.H.P., *Gloire*, 20,500 I.H.P., *Leon Gambetta*, 27,500 I.H.P.; the following battleships, *Requin*, 7,000 I.H.P., *Henri IV*, 11,500 I.H.P., *Suffren*, 16,500 I.H.P., *Marceau*, 14,000 I.H.P., and others.

This list embraces only the heaviest orders from the principal navies.

It is but natural, of course, that we should have generally, and with reason, more confidence in the results of our own experiments than in those of others, but it is impossible not to be struck by the similarity of good results obtained in all others than the German Navy, even with boilers identical with those of the *Freya* and *Gazelle*. From this we can conclude that had the German Navy not shown such prudence, perhaps a little excessive, in the matter of the lanterns, and had put these two ships in commission directly after the completion of their early successful trials, the success of the German service would have been equal to, and possibly greater than, that of other nations, and that the *Freya* and *Gazelle* would have been giving full satisfaction since October, 1898.

By an express order, however, given by the Imperial German Department of the Marine, the replacing of the malleable-iron lanterns by seamless steel ones was required, the discussion before deciding upon the change, and the time required to make that change, having been, unfortunately, very long.

This explains the first period of the delay, and we will now pass on to the second.

In October, 1900, the trials began again, with the boilers fitted with the new lanterns. Those of the *Gazelle* were without incident and were very good. During the first trial with forced draft of the *Freya* at Dantzic, one boiler became overheated, but no serious damage was done, the renewal of one tube and the straightening of a few others being the only repairs required. Mr. Kohn Von Jaski states that the cause of this was the poor circulation of the water in the tubes.

The Schiff und Maschinenbau Aktien Gesellschaft Germania informed us that the German authorities were of the opinion that the flow of water in the internal tubes and the escape of steam from the outer tubes had been impeded, and requested the making of a few alterations: 1st. The addition of a small ring around the lanterns where they pass through the diaphragm plate of the header, in order to make the diaphragm more nearly watertight. 2d. A change in the method of securing the internal tubes to the plugs, in order to avoid the impedence of the water circulation on account of the bracket arms coming in front of the openings in the lanterns.

When the trouble was first reported to us, our first thought was that the feed arrangements had been faulty, due to defects in the pumps, as had been the case on the first trial of the *Garibaldi*, also mentioned by Mr. Von Jaski. As the crew declared that this was not the case, and that everything went on smoothly in the fire room, we accepted the official findings, and asked only for permission to carry out the trials without altering the boilers, and to increase the coal consumption above the maximum requirement—that is, up to 170 to 200 kilograms instead of 150 kilograms per square meter of grate surface. We had made such combustion trials in the shop in Paris, with boilers identical in all respects, including the seamless steel lanterns, with those of the *Freya*.

The authority to make these trials being refused, we made no objections to the proposed alterations which, however, we consider useless although harmless.

After these alterations were completed, the boilers were put together. The work of assembling them was done under the supervision of one of our own men.

The following is a fact, and one of importance, which Mr. Kohn Von Jaski has neglected to mention in his article.

We have, ourselves, seen in November, 1900, that the putting together of the boilers had not been properly carried out. The tubes, instead of being so placed that the openings in the lanterns would be on the top and bottom, were placed with these openings on the sides. The solid parts of the lanterns being on the tops and bottoms, were sufficient to impede the circulation of the water and to interfere with the free escape of the steam. This is very easily seen by an examination of plans of these boilers.

This arrangement of the tubes was another point of evidence showing that our tools had not been used in the setting of the tubes, for with them it is necessary to place the tubes in the proper position. In the *Gazelle's* boilers, the tubes were correctly placed, and the trials passed off successfully.

The first modification necessary in the *Freya's* boilers, therefore, was to set the tubes in the correct manner.

The successive trials of the *Freya* at a coal consumption of 130, 150 and 170 kilograms per square meter of grate, and of the *Gazelle* at 180 kilograms, together with the trials in free route, have been completely successful.

Immediately after the first trials we again requested authority to make the same trials on our own responsibility, with a boiler in which the ordered changes had not been made, but in the same conditions as on board the *Freya*, that is, with the boilers inclined aft.

We deeply regretted that this authorization was not given, as it deprived us of the means of irrefutably proving that the Niclausse boiler was not responsible for the Dantzic incident, which had, however, unfortunately delayed the putting into service of the two ships.

The success of the high-consumption trials seems to us to

be a sufficient proof that we were not responsible for the second delay.

In a period of thirteen days, from March 21 to April 2, the following trials were made with the *Freya;* six hours at forced draft, with 10,400 I.H.P. instead of 10,000; two coal-consumption trials, each of twenty-four hours' duration, at 1,200 and 6,000 I.H.P.; and one trial of seventy-two hours' duration at 6,000 I.HP.

We will now reply to certain objections made by Mr. Kohn Von Jaski on the principles of construction of the Niclausse boiler.

We will state that the Reiche Marine Amt has made trials of the *Freya* in very unfavorable conditions, so far as relates to the inclination of the boilers, more unfavorable even than during the Dantzic trials, and no trouble has developed.

We ourselves have made some experiments which, if so desired, can be easily repeated before representatives of the German Navy, which showed that so long as the tubes had a very slight inclination, less than one per cent., the circulation remains perfect.

We would also state that the *Cristobal Colon* and the *Khrabry* have their boilers placed athwartships, and the rolling of these ships has never produced any trouble in the circulation in the boilers.

Mr. Kohn Von Jaski writes: "The French press have not allowed any accidents to Niclausse boilers to become known; it may, however, be surmised that such must also have occurred on board French war ships." We cannot understand why Mr. Von Jaski made such a statement as on no grounds can it be justified. In addition, the German Navy has every facility to secure official information through its naval attaché.

When we take into account the bitter competition that exists among the manufacturers of the different types of boilers, we are forced to acknowledge that the correspondent who should dare to misrepresent the facts of the case, as was done in the case of the *Garibaldi*, would not miss the opportunity of exploiting any serious faults, should they have existed.

Mr. Kohn Von Jaski also considers that in the Niclausse system of construction there exists a certain amount of excess pres-

sure tending to force the tubes from their seatings in the headers and to project them into the fire rooms.

Every one who has visited our shops has seen our headers tested, with the tubes in position, at a pressure of twenty-five kilograms per square centimeter, and without the securing dogs. Not only is no tube thrown out from its seatings, but there is an absolute tightness at the joints. This result is entirely due to the principle of construction by which the tube is in perfect equilibrium.

The arrangement for securing the tubes in the Niclausse boiler seems, generally, more advantageous than that to which Mr. Kohn Von Jaski gives preference in his article. He recommends a very similar boiler in which the lanterns do not exist, and in consequence, the pressure does tend to force out the handhole plugs over the tubes, as there is no connection between plug and tube. If the tubes are straight, the tendency is for the pressure to force the tube directly through its bearing seat, but if the tube is bent, there is also a tendency for the tube to swing in the joint and thus produce a leak.

In the Niclausse boiler, the arrangement of tubes possesses a great advantage in the ease with which tubes can be drawn out from the front. In the other nearly similar boiler, space must be reserved behind the boiler to permit of knocking the tubes out of their seatings and pushing them to the front through the water space, in order to allow of their withdrawal at the front. In consequence a boiler of this latter kind requires considerably more floor space than is required by the Niclausse.

Mr. Kohn Von Jaski fears that the tube threads will give trouble in time.

We will answer to this that we can show boilers which have been in use for eleven years and in which the threads are as perfect to-day as upon leaving our shops.

He also declares that the blow-off cocks of the *Gazelle* have given trouble through leakage. We have had nothing whatever to do with either the design or construction of these cocks.

Mr. Kohn Von Jaski concludes his criticism of the Niclausse boiler by saying, "there is no reason why we should exchange

the proved and solid construction" of boilers very similar to ours and already well known in Germany. This is a personal opinion sincerely expressed, and to which, as such, we can only bow our heads. We will only appeal to the good faith of the author to first examine the above statements and then compare the place taken in all navies by the Niclausse boilers with that occupied by the boiler of his choice.

Such a comparison will most certainly result in favor of the Niclausse boiler.

Finally, we call upon him to analyze the advantages presented by the Niclausse system, in the small space occupied, in the facilities for inspection of, and for cleaning the interior, and, above all, the ease and rapidity with which the exterior of the tubes can be swept by the use of the steam jet, sweeping being so essential in preventing an undue increase in coal consumption after being under way a few days.

WATER-TUBE BOILER INSTALLATIONS OF THE WORLD'S NAVIES.

COMPILED BY LIEUTENANT CHARLES W. DYSON, U. S. N.

While data is at all times valuable for reference, yet a great amount of its value depends upon its degree of accessibility and the form in which it is presented. The pages of the JOURNAL are full of valuable information, but as, in order to get enough of this on any one subject for practical use, it was necessary to search through volume after volume, I determined to collect all data concerning water-tube boilers which had already been published and put it in convenient tabular form for reference.

While in the cases of some of the vessels the boiler details are extremely meagre, I decided to give them places in the tables, trusting to the future to supply the deficiencies in some of them.

The results given for United States vessels under the heads of "Moderate speed" and "Full power, natural draft" are taken from performances during actual cruising service of the vessels, and do not make quite as good a showing as if the ships were using selected coal under trial conditions.

Where weight of machinery or boilers is given, it includes all appurtenances and water unless otherwise stated. The tables follow.

Name.	Nation	Type	Displacement	Boilers. Grate surface	Boilers. Heating surface	Designed. IHP	Designed. Speed	Coal consumption at moderate speed. IHP	Coal consumption at moderate speed. Speed	Coal consumption at moderate speed. Coal per IHP	Continuous full-power trial. Natural draft. IHP	Continuous full-power trial. Natural draft. Speed	Continuous full-power trial. Natural draft. Coal per IHP
BABCOCK AND WILCOX.													
Queen	B	B S	15,000	1,147	38,400	15,000	18	...	...	...	...	...	...
New Jersey	U S	B S	14,600	1,342	56,184	19,000	19	...	...	...	...	...	...
Rhode Island	U S	B S	14,600	1,342	56,184	19,000	19	...	...	...	...	...	...
Challenger	B	P C	5,880	...	...	12,500	...	...	...	...	...	...	...
Sheldrake	B	G B	735	252	9,424	3,500	19	1,303	...	1.61	2,245	...	1.63
Espiegle	B	G B	1,070	143 9	4,040	1,400	13.25	337.4	10	1.53	1,032.6	13 5	1.54
Cincinnati	U S	P C	3,000	507	21,130	7,500	19	...	...	...	...	...	...
Raleigh	U S	P C	3,000	507	21,130	7,500	19	...	...	...	...	...	...
Denver	U S	P C	3,200	300	13,200	4,500	16.5	...	...	...	...	...	...
Desmoines	U S	P C	3,200	300	13,200	4,500	16 5	...	...	...	...	...	...
Chattanooga	U S	P C	3,200	300	13,200	4,500	16.5	...	...	...	...	...	...
Galveston	U S	P C	3,200	300	13,200	4,500	16.5	...	...	...	...	...	...
Tacoma	U S	P C	3,200	300	13,200	4,500	16.5	...	...	...	...	...	...
Cleveland	U S	P C	3,200	300	13,200	4,500	16.5	...	...	...	...	...	...
Milwaukee	U S	P C	9,700	1,400	64,000	21,000	22	...	...	...	...	...	...
Odin	B	Sloop	1,070	143.9	4,040	1,400	13 25	...	...	...	...	...	...
Annapolis	U S	G B	931.25	98	3,620	800	12	...	...	...	...	...	...
Marietta	U S	G B	996	94	3,664	800	12	256.8	8.57	1.52	...	...	...
Wyoming	U S	M	3,235	200	8,800	2,400	11½	...	...	...	...	...	...
BELLEVILLE.													
Azuki	J	B S	15,200	...	37,936	15,000	18	4,355	13.06	...	12,947	17 5	1.59
Albemarle	B	B S	14,000	1,375	43,260	18,000	19	...	...	...	...	...	...
Amiral Trehouart	F	B S	6,534	...	...	8,500	17	...	...	...	...	...	...
Arpad	A	B S	8,340	...	...	11,900	18.5	...	...	...	...	...	...
Brennus	F	B S	10,983	1,100.5	35,030.8	14,000	...	...	...	...	...	...	...
Bouvet	F	B S	12,205	1,128	32,175	14,000	17	...	...	...	...	...	...
Borodino	R	B S	13,600	...	...	16,300	...	...	...	...	...	...	...
Benedetto Brin	I	B S	13,500	...	...	18,000	20	...	...	...	...	...	...
Bulwark	B	B S	15,000	1,170	37,160	15,000	18	3,174	11.2	...	11,755	16.8	...
Charlemagne	F	B S	11,260	...	...	14,500	18	5,170	14	1.48	11,460	17.25	1.63
Canopus	B	B S	12,950	1,050	33,793	13,500	18	2,813	11.3	1 82	10,457	17.2	1.68
Cornwallis	B	B S	14,000	1,375	43,260	18,000	19	...	...	...	...	...	...
Devastation	F	B S	10,000	...	...	8,000	15	...	...	...	...	...	...
Duncan	B	B S	14,000	1,375	43,260	18,000	19	...	...	...	...	...	...
E. Katerena II	R	B S	10,181	...	...	11,000	16	...	...	...	...	...	...
Emp. Nicholas I	R	B S	9,700	...	7,312* 10,563†	8,000	16	...	...	...	...	...	...
Emp. Alexander II	R	B S	9,900	...	...	8,000	16	...	...	...	...	...	...
Kniaz Swaraff	R	B S	13,600	...	...	16,300	18	...	...	...	...	...	...
Exmouth	B	B S	14,000	1,375	43,260	18,000	19	...	...	...	...	...	...
Formidable	B	B S	15,000	1,170	37,120	15,000	18	3,269	11.5	...	11,618	16.81	...
Goliath	B	B S	12,950	1,050	33,158	13,500	18	2,807	11.7	1.73	10,413	17 1	1.54
Glory	B	B S	12,950	1,035	35,715	13,500	18	2,879	10.8	2.15	10,587	16 78	1.70
Gaulois	F	B S	11,260	...	...	14,500	...	5,170	14.31	1.35	9,200	16.5	1.53
Hoche	F	B S	10,650	866.5	...	11,500	16	...	...	...	...	...	...
Hainue	J	B S	15,000	...	...	15,000	18	...	...	...	...	...	...
Irresistible	B	B S	15,000	1,170	37,120	15,000	18	3,243	11.76	2.40	11,626	17.5	2.09
Jena	F	B S	12,052	1,028.3	...	15,500	18	5,504	13.8	...	9,830	16.3	...
K. Karl VI	A	B S	6,250	918	35,000	12,000	20	...	...	...	...	...	...
London	B	B S	15,000	1,170	37,160	15,000	18	3,237	11.5	1 81	11,718	16.4	1.8
Montague	B	B S	14,000	1,375	43,260	18,000	19	...	...	...	...	...	...
Mikasa	J	B S	15,200	1,276	37,452	15 000	18	...	...	...	12,325	17.36	1.53
Neptune	F	B S	10,630	...	...	11,000	...	...	...	...	...	...	...
Ocean	B	B S	12,950	1,035	11,560* 24,155†	13,500	18	2,767	11.4	1.84	10,314	16.2	1.63
Orel	R	B S	13,600	...	...	16 300	...	...	...	...	...	...	...
Ostyaba	R	B S	12,674	1,393	43,450	14 500	18	...	...	...	...	...	...
Peresviet	R	B S	12,674	1,393	43,450	14,500	18	...	...	...	...	...	...
Prince Polemkin	R	B S	...	...	...	10,600	...	...	...	...	...	...	...
Pobyeda	R	B S	12,674	1,393	43,418	14,500	...	...	...	...	...	...	...
Russell	B	B S	14,000	1,375	43,260	18,000	19	...	...	...	...	...	...
St. Louis	F	B S	11,260	...	...	14,500	...	...	...	...	...	...	...
Sinope	R	B S	10,181	...	...	13,000	17.8	...	...	...	...	...	...
Shikishima	J	B S	14,850	...	40,000	14,500	18	...	...	...	...	...	...
Tsesarevitch	R	B S	13,110	...	...	16,300	18	...	...	...	...	...	...

* Economizer. † Boiler.

Full power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq. ft. Grate.	IHP per sq. ft. Grate.	IHP per sq. ft heat	Air press.	
BABCOCK AND WILCOX.							
...	...	...	...	...	...	...	Weight boiler installation, 1,530 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
4,050	20.6	1.57	25	16.07	.430	.5	
1,416.8	13.5	1.70	16.74	9.84	.351	...	
...	...	...	...	...	...	...	Weight of dry boilers, 191 tons.
...	...	...	...	...	...	...	Weight of dry boilers, 191 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
1,215	13.7	...	...	...	...	.9	Total weight machinery, 137 tons,
1,030	13.2	...	...	...	...	.36	Total weight machinery, 124.82 tons; weight boiler inst., 50 tons.
...	...	...	...	...	...	...	
BELLEVILLE.							
16,000	18.3	...	...	...	.422	...	
...	...	...	...	...	...	...	Weight of machinery, 1,580 tons.
9,250	17.5	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	18.18	...	...	...	...	...	Weight boiler installation, 580.38 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
15,353	18.15	1.83	24.01	13 12	.413	...	
15,295	18.14	1.92	...	...	...	...	
13,763	18.5	1.72	22.53	13.1	.407	.19	Weight of machinery, 1,290 tons.
...	...	...	...	...	...	...	Weight of machinery, 1,580 tons.
8,302	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 1,380 tons.
...	...	...	...	...	...	...	
5,000 ?	15.9	...	...	...	...	...	
...	16.5	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 1,580 tons.
15,571	18.13	1.8	23.87	13.26	.418	...	Weight of machinery, 1,400 tons.
13,018	18 4	1.91	25.31	13.25	.419	...	Weight of machinery, 1,290 tons.
13,745	18.124	1.58	20.98	13.28	.385	...	Weight of machinery, 1,290 tons.
14,925	18.2	1.77	...	...	...	...	
11,836	16	...	...	13.66	...	...	
...	19.1	...	...	...	...	...	
18,603	18.2	1 97	26.28	13.34	.420	...	Weight of machinery, 1,400 tons.
16,500	18.2	1.72	27 6	16.05	...	...	
12,900	20.83	...	...	14.05	.368	3.94	Weight of machinery, 1,110 tons.
15,264	18	1.97	25.69	13.04	.411	.2	
...	...	...	...	...	...	...	Weight of machinery, 1,580 tons.
16,432	18 54	...	...	12.88	.438	...	Weight of machinery, 1,355 tons.
...	...	...	...	...	...	...	
13,828	18.74	1.76	23.51	13.36	.387	...	Weight of machinery, 1,290 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Wt. boiler and fittings, 876 t.; eng. and fittings, 860 t.; all mach'y.
13,775	19.12	...	...	9.88	.317	...	Wt. boiler and fittings, 876 t.; eng. and fittings, 860 t.; all mach'y.
...	...	...	...	...	...	...	
15,492	18.51	2.63	29.47	11 12	.357	...	
...	...	...	...	...	...	...	Weight of machinery, 1,580 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
13,000	19.02	...	...	...	.375	...	
...	...	...	...	...	...	...	

Name.	Nation	Type	Displacement	Boilers.		Designed.		Coal consumption at moderate speed.			Continuous full-power trial. Natural draft.		
				Grate surface	Heating surface	IHP	Speed	IHP	Speed	Coal per IHP	IHP	Speed	Coal per IHP
Albion	B	B S	12,950	1,072.5	11,560* 24,155†	13,500	18	2,772	11.2	2.17	10,809	16.8	1.81
Implacable	B	B S	15,000	1,190.47	37,164	15,000	18.0	3,179	11	1.95	11,853	16.75	1.65
Habsburg	A	B S	8,340	...	...	11,900	18.5	...	...	...	...	...	...
Vengeance	B	B S	12,950	1,050	12,010* 21,770†	13,500	18.25	2,885	11.35	1.69	10,387	17 49	1.51
Prince of Wales	B	B S	15,000	1,147	37,040	15 000	18	...	...	...	...	...	...
Venerable	B	B S	15,000	1,170	37,160	15,000	18	...	...	...	...	...	...
Courbet	F	B S	10,000	...	...	8,000	15	...	...	...	...	...	...
Gremiastchy	R	A C D	1,492	...	...	2,000	13.5	...	...	...	...	...	...
Otvajny	R	A C D	1,492	...	...	2,000	13.5	...	...	...	...	...	...
Grosiastchy	R	A C D	1,492	...	...	2,000	13.5	...	...	...	...	...	...
Rostislav	R	B S	8,880	...	...	8,500	16	...	...	...	...	...	...
Amiral Aube	F	A C	10,014	...	...	20,500	21	...	...	...	...	...	...
Amiral Charner	F	A C	4,750	...	...	8,300	18.5	...	...	...	...	...	...
Adzuma	J	A C	9,456	...	...	17,000	21	...	...	...	...	...	...
Aboukir	B	A C	12,000	1,650	51,577	21,000	21	4,597	14 4	1.90	16,274	20.42	1.77
Admiral Nakimoff	R	A C	8,500	...	...	9,000	19	...	...	...	...	...	...
Bayan	R	A C	7,800	1,378	43,050	17,000	21	...	...	...	...	...	...
Bacchante	B	A C	12,000	1,650	51,500	21,000	21	4,624	13.6	1.8	16,445	20.6	1.75
Bedford	B	A C	9,800	1,610	17,200* 33,100†	22,000	23	...	...	...	...	...	...
Bruix	F	A C	4,750	...	...	8,800	19	...	...	...	...	...	...
Chiyoda	J	A C	2,450	...	...	5,500	19	...	...	...	...	...	...
Chanzy	F	A C	4,750	...	...	8,300	18.5	...	...	...	...	...	...
Cressy	B	A C	12,000	1,650	51,577	21,000	21	4,731	13.89	1.87	16,270	20.196	1.79
Drake	B	A C	14,100	2,310	71,970	30,000	23	...	...	...	...	...	...
Desaix	F	A C	7,700	...	...	17,000	21	...	...	...	...	...	...
Dupetit Thouars	F	A C	9,516	...	...	19,600	20	...	...	...	...	...	...
Dupleix	F	A C	7,700	...	...	17,100	21	...	...	...	...	...	...
Essex	B	A C	9,800	1,610	17,200* 33,100†	22,000	23	...	...	...	...	...	...
Euryalus	B	A C	12,000	1,650	51,500	21,000	21	...	...	...	...	...	...
F. Ferruccio	I	A C	7,400	...	...	13,500	20	...	...	...	...	...	...
Gromoboi	R	A C	12,336	...	47,021	18,000	20	...	...	...	...	...	...
Good Hope	B	A C	14,100	2,310	71,970	30,000	23	6,054	14.5	1.87	22,703	22 09	1.83
Hogue	B	A C	12,000	1,650	51,500	21,000	21	4,738	13	2.09	16,456	20.15	2.05
Iwate	J	A C	9,800	...	...	15,000	20.7	...	...	...	...	...	...
Idzumo	J	A C	9,800	...	...	15,000	20.75	...	...	...	...	...	...
Kent	B	A C	9,800	1,610	50,300	22,000	23	...	...	...	...	...	...
King Alfred	B	A C	14,100	2,323	7,200	30,000	23	...	...	...	...	...	...
Latouche Treville	F	A C	4,750	694	19,526	8,300	18.5	...	...	...	...	...	...
Monmouth	B	A C	9,800	1,610	17,200* 33,100†	22,000	23	...	...	...	...	...	...
Marseillaise	F	A C	10,014	...	...	20,500	21	...	...	...	...	...	...
Minin	R	A C	6,200	...	...	5,290	12.5	...	...	...	...	...	...
Leviathan	B	A C	14,100	2,323	72,000	30,000	23	...	...	...	...	...	...
Pueyrredon	Arg	A C	6,882	...	...	13,000	20	...	...	...	...	...	...
Powerful	B	A C	14,200	2,193.6	69,576	25,000	22.25	5,008	14	2.07	18,433	20.56	1.83
Pamyat Azova	R	A C	6,700	...	...	11,000	18.8	...	...	...	...	...	...
Rossiya	R	A C	12,200	...	...	17 000	19	...	...	...	...	...	...
Sully	F	A C	10,014	...	...	20,500	21	...	...	...	...	...	...
Spartiate	B	P C	11,000	1,390	47,300	18,000	20.75	3,834	12.3	1.83	...	...	...
Sutlej	B	A C	12,000	1,658.5	51,768	21,000	21	4,641	14.13	1.99	16,604	20 63	1.90
Terrible	B	A C	14,200	2,193.6	69,576	25,000	22.25	5,111	13.43	2.57	18,493	20.96	1.71
Varese	I	A C	7,400	1,047.5	11,968* 21,942†	13,500	20	...	...	...	9,479	18.36	...
Yakumo	J	A C	9,850	...	...	16,000	20	...	...	...	...	...	...
Amphitrite	B	P C	11,000	1,390	47,300	18 000	20.75	3,751	12.8	1.54	13,695	19 52	1.43
Ariadne	B	P C	11,000	1,390	47,300	18,000	20.75	3,758	13 3	2.05	14,046	20.1	1.73
Alger	F	P C	4,122	754	22,261	8 000	19 5	...	...	...	...	...	...
Aurora	R	P C	6,630	1,162	36,060	11.610	20.	...	...	...	...	...	...
Argonaut	B	P C	11,000	1,390	47,300	18,000	20.75	3,756	13.15	2.13	13,815	19 86	1.6
Arrogant	B	P C	5,750	860	23,000	10,000	19	...	...	...	7,624	17.8	2 1
Andromeda	B	P C	11,000	1,450	40,140	16,500	20.5	3,388	12.9	1.98	12,621	19.3	1.74
Baquedano	Chili	P C	2,500	...	...	1.500	12	...	...	...	...	...	...
Boyarin	R	P C	3,000	...	...	11,500	22	...	...	...	...	...	...
Bugeaud	F	P C	3,722	757.6	21,593	9,000	19.5	...	...	...	...	...	...

* Economizer. † Boiler.

Full power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq.ft. Grate.	IHP per sq.ft. Grate.	IHP per sq.ft. heat.	Air press.	
13,885	17.8	2.04	26.42	12.95	.389	...	Weight of machinery, 1,290 tons.
15,362	18.22	1.87	23.97	12.82	.411	...	Weight of machinery, 1,400 tons.
...	...	...	...	...	...	...	
13,852	18.5	1.72	22.69	13.19	.410	...	Weight of machinery, 1,290 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
2,034	...	...	...	...	...	...	
2,034	...	...	...	...	...	...	
2,034	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
21,375	21.6	1.84	23.88	12.95	.414	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
21,520	21.7	1.70	22.17	13.04	.418	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
21,240	20.7	1.93	24.84	12.87	.412	...	Weight of machinery, 1,800 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 2,540 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 1,800 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
15,496	...	...	...	...	.329	...	
31,071	23.05	1.92	25.7	13.4	.431	.2	Weight of machinery, 2,540 tons.
21,432	22.06	2.06	26.75	12.98	.416	...	Weight of machinery, 1,800 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 2,540 tons.
8,168	...	1.806	21.21	11.77	.418	...	Weight of boiler installation, 352.5 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 2,540 tons.
13,384	19.94	...	...	...	...	...	
25,886	21.8	...	...	11.80	.372	...	Weight of machinery, 2,235 tons.
...	...	...	...	...	...	...	Weight of boilers, complete, 1,164 tons.
18,446	19.7	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight of machinery, 1,630 tons.
22,262	21.77	2.36	29.26	12.82	.411	...	
25,572	22.41	...	...	11.66	.367	.32	Weight, complete, machinery, 2,225 tons; boilers, 1,148 tons.
13,630	20.02	1.92	24 98	13.03	.402	.75	
...	...	...	...	...	...	...	
18,229	20.94	1.57	20.6	13.12	.385	A D	Weight of machinery, 1,630 tons.
19,156	21.5	1.66	22	13.2	.405	.23	Weight of machinery, 1,630 tons.
8,202	...	1.714	18.64	10.88	.368	...	Weight of boiler installation, 437.5 tons.
...	...	...	...	...	...	...	
18,894	21 17	1.6	21.9	13.6	.399	.21	Weight of machinery, 1,630 tons.
10,290	19.6	...	...	11.96	.448	A D	No economizers.
16,751	20.41	1.76	20.33	11.55	.417	A D	Boiler-room weights, 765; engine-room weights, 750.
...	13 7	...	...	...	...	N D	
...	...	...	...	...	...	...	
9,440	...	2.06	25.68	12.46	.437	...	Weight boiler installation, 407.39 tons.

Name.	Nation	Type	Displacement	Boilers. Grate surface	Boilers. Heating surface	Designed. IHP	Designed. Speed	Coal consumption at moderate speed. IHP	Coal consumption at moderate speed. Speed	Coal consumption at moderate speed. Coal per IHP	Continuous full-power trial. Natural draft. IHP	Continuous full-power trial. Natural draft. Speed	Continuous full-power trial. Natural draft. Coal per IHP
Catinat	F	P C	4,065	730.7	...	9,000	19	...	...	...	6,455	17 5	1.51
Condell	Chili	TGB	750	...	...	4,000	20	...	...	...	...	...	...
Diadem	B	P C	11,000	1,480	10,950* 29,600†	16,500	20.5	3,318	12.64	2.21	12,813	19-53	1.62
Diana	R	P C	6,630	1,162	36,060	11,610	20	...	...	...	...	...	...
Descartes	F	P C	3,985	...	...	8,500	20	...	...	...	...	...	...
Europa	B	P C	11,000	1,469	10,980* 29,620†	16,500	20.5	3,319	12.9	2.23	12,770	...	1.94
Furious	B	P C	5,750	860	23,000	10,000	19	2,260	13.6	2.34	7,133	18 7	2.10
Galilee	F	P C	2,317	...	...	6,600	20	...	...	...	...	...	...
Gladiator	B	P C	5,750	860	23,000	10,000	19	2,162	11.8	2.16	7,154	17-5	1.90
Hermes	B	P C	5,600	750	24,050	10,000	20	2,151	13.4	1.78	7,705	18 8	1.57
Highflyer	B	P C	5,600	750	24,000	10,000	20	2,135	12.5	1.63	7,644	19 4	1.49
Hyacinth	B	P C	5,600	750	24,000	10,000	20	2,135	12.1	1.73	7,718	17-34	1.47
Hansa	G	P C	6,100	794.4	23,832	10,000	18.5	...	...	...	...	...	...
Hertha	G	P C	6,100	794.4	23,832	10,000	18.5	2,731	...	3-94	7,001	...	2.11
Itsukushima	J	P C	4,277	...	...	5,400	16.7	...	...	...	...	...	...
Levrier	F	TGB	925	...	...	2,000	18	...	...	...	...	...	...
Lavoisier	F	P C	2,317	...	...	6,400	20	...	...	...	4,560	18.6	1.63
Lynch	Chili	TGB	750	...	...	4 000	20	...	...	...	...	...	...
Leger	F	TGB	925	...	...	2,000	18	...	...	...	...	...	...
Niobe	B	P C	11,000	1,441	10,962* 29,588†	16,500	20.5	3,348	12	1.76	12,968	19.27	1.35
Milan	F	P C	1,733	...	...	4,600	18	...	...	...	...	...	...
O' Higgins	C	P C	8,500	...	...	16 500	21.25	...	...	...	...	...	...
Pallada.	R	P C	6,630	1,162	36,060	11 610	20	...	...	...	...	...	...
Pascal	F	P C	3,589	...	...	8,500	20	...	...	...	...	...	...
Protet	F	P C	4,065	...	...	9,000	20	...	...	...	...	...	...
Pothuau	F	P C	5,365	802	...	10,000	19	...	...	...	6,845	17-79	...
Svyethlana	R	P C	3,828	...	...	8,500	20	...	...	...	...	...	...
Tripoli	I	TDV	850	...	...	3,600	20	...	...	...	...	...	...
Vindictive	B	P C	5,750	860	23,000	10,000	19	2,153	12.6	2.16	7,164	17-7	1.83
Condor	B	G B	1,070	136.8	4,000	1,400	13.25	...	...	...	...	...	...
Rosario	B	G B	1,070	136.8	4,000	1,400	13 25	...	...	...	...	...	...
Sharpshooter	B	G B	735	...	...	3.500	19	...	...	...	...	...	...
Budapest	A	ACD	5,550	720	22,500	9 000	17.5	...	...	...	6,608	...	...
Furieux	F	ACD	5,800	...	...	5,000	...	...	...	...	...	...	...
Mutine	B	Sloop	980	135.7	4,030	1,400	13.25	329.9	8.1	1.86	1,044.7	12.2	1.71
Vestal	B	Sloop	1,070	136.8	4,000	1,400	13.25	...	...	...	...	...	...
Shearwater	B	Sloop	1,070	136.8	4,000	1 400	13.25	...	...	...	...	...	...
Rinaldo	B	Sloop	980	135.7	4,030	1,400	13.25	312.7	8.8	1 90	1 030	13 0	1.60
Royal Yacht	B	Yacht	4,300	834	26,000	11,000	20	5,142	16.32	1.94	7,649	18.47	1.87
BLECHYNDEN.													
Agordat	I	P C	1,313	376.75	20,495	7,500	23	...	...	...	...	...	...
Chatil	I	P C	1,313	...	...	8,000	23	...	...	...	...	...	...
Pomone	B	P C	2,135	350	17,504	7,000	20	3,600	16 5	2.44	5,541	20.2	...
Pactolus	B	P C	2,135	349.7	17,504	7,000	20	3,631	1.18‡	2.46	5,428	1.12‡	...
Sturgeon	B	TBD	270	...	...	4,000	27	...	...	...	...	...	...
Starfish	B	TBD	270	...	...	4,000	27	...	...	...	...	...	...
Skate	B	TBD	270	...	...	4,000	27	...	...	...	...	...	...
Minerva	I	T C	846	...	...	4,200	22	...	...	...	...	...	...
WHITE.													
Zebra	B	TBD	320	210	11,250	4,800	27	...	...	...	...	...	...
Conflict	B	TBD	315	210	11,250	4,500	27	...	...	...	...	...	...
Teaser	B	TBD	315	210	11,250	4.500	27	...	...	...	...	...	...
Wisard	B	TBD	315	210	11,250	4,500	27	...	...	...	...	...	...
DÜRR.													
Baden	G	B S	7,400	517	16,750	6,000	17	4,480	...	2.62	5,006	...	2
Bayern	G	B S	7,400	454	21,800	6,000	17	5,296	...	2.28	5,002	...	1.96
Sachsen	G	B S	7,400	437	18,250	6,000	17	...	...	...	5,143	...	1.96
Prinz Heinrich	G	A C	3,868	1,089	46,223	15,000	20.5	...	...	...	...	...	...
Lussin	A	TGB	1,011	...	...	1,830	14	...	...	...	...	...	...
Vineta	G	P C	5,630	598.8	27,360	10,000	19	3,800	...	2.08	8,530	...	2.29
Victoria Louise	G	P C	5,630	674.25	27,825	10,000	19	5,040	...	1.86	6,055	...	1.69
Jaguar	A	T C	...	...	...	7,700	20	...	...	...	...	...	...

* Economizer. † Boiler. ‡ Air pressure. § Estimated.

Full power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq ft. Grate.	IHP per sq.ft. Grate.	IHP per sq.ft heat.	Air press.	
9,938	19.62	1.75	23.8	13.6	...	...	
4,350	20.3	...	...	...	...	...	
17,262	20.65	1.77	20.50	11.64	.424	A D	Boiler-room weights, 748 tons; engine-room weights, 764 tons.
...	...	...	...	...	...	...	
8,720	19.7	...	...	...	...	...	
17,026	20.5 ?	1.91	22.25	11.65	.419	A D	Boiler-room weights, 762 tons; engine-room weights, 782 tons.
10,272	20.1	...	...	11 94	.447	A D	No economizers.
6,846	19.8	...	...	...	...	...	Afterwards made 20 knots.
10,120	19.1	2.31	27.19	11.77	.482	...	No economizers.
10,364	20.5	1.58	21.65	13.7	.423	...	Weight of machinery, 870 tons; boilers, 470 tons.
10,344	20.1	1.407	19 42	13 8	.431	...	Weight of machinery, 870 tons; boilers, 470 tons.
10,536	19.4	1.58	22.20	14.05	.439	...	Weight of machinery, 870 tons; boilers, 470 tons.
10,050	...	...	...	12.4	.395	...	Weight of boilers, 472 tons.
9,928	...	...	...	12.6	.400	...	Weight of boilers, 449 tons.
...	...	...	...	...	...	...	
2,300	18.5	...	...	...	...	...	
7,450	21.5	...	...	...	...	...	
...	...	...	...	...	...	...	
2,230	18.8	...	...	...	...	...	
16,834	20.5	1.66	19.29	11.62	.415	A D	Weight, complete, boilers, 773 tons; engines, 795 tons.
4,132	18 4	...	...	...	...	...	
...	21.52	...	...	...	...	...	
...	...	...	...	...	...	...	
8,600	19.7	...	...	...	...	...	
...	...	...	...	...	...	...	
10,256	19.20	1.89	24.17	12.79	...	...	
...	21.60	...	...	...	...	...	
...	...	...	...	...	...	...	
10,263	20.1	...	...	11.93	.446	A D	No economizers.
1,459	13.68	1.56	16.86	10.67	.365	N D	
1,483	13.60	1.92	20.81	10.84	.371	N D	
...	...	...	...	...	...	...	
9,185	17 87	...	...	12.76	.408	.2	
5,033	13.8	...	...	...	...	...	
1,490.7	14.55	1.63	17.90	10.98	.369	N D	
1,487	13 569	1.53	16.86	10.87	.372	N D	
1,441	13.50	1.56	16.43	10.53	.360	N D	
1,434.9	13.50	1.61	17.02	10 57	.356	N D	
11,298	20.53	...	...	13.55	.434	...	Weight of machinery, 950 tons.
BLECHYNDEN.							
8,550	22.2	...	...	22.69	.417	2.2 to 3	Weight of machinery, 285 tons.
...	...	...	...	...	...	...	
7,340	20.8	2 45	31.38	20 97	.419	2.77	Air pres., (1) .87; (2) 1.40; wt., comp., machy, 360.5; boilers, 170.5
7,201	20.5	...	...	20.99	.412	3.3	Weight, complete, machinery, 388 tons; boilers, 188 tons.
...	27.1	...	...	...	...	...	
...	27.8	...	...	...	...	...	
...	27.5	...	...	...	...	...	
...	...	...	...	...	...	...	
WHITE.							
4,816	27.003	...	...	...	...	...	
...	27.102	...	...	...	...	...	
...	27.112	...	...	...	...	...	
...	27.164	...	...	...	...	...	
DURR.							
6,118	...	2.0	23 67	11 8	.366	...	
6,080	15.5	1.56	21.59	13.8	.388	...	
6,370	...	2.06	36.03	14.5	.348	...	
16,825	...	2.20	34	15.45	.384	...	
...	...	...	...	...	...	...	
11,580	...	2.12	41	19.34	.493	1.375	
12,911	...	1.88	36	19.2	.397	1.125	Weight of boilers, 391.75 tons.
...	...	...	...	...	...	...	

Name.	Nation	Type	Displacement	Boilers.		Designed.		Coal consumption at moderate speed.			Continuous full-power trial. Natural draft.		
				Grate surface	Heating surface	IHP	Speed	IHP	Speed	Coal per IHP	IHP	Speed	Coal per IHP
GUYOT-DU TEMPLE.													
Jeanne D'Arc	F	A C	11,270	1,636	76,273	28,500	23	...	...	...	...	...	...
Jurien-de-la-Graviere	F	P C	5,500	...	...	17,100	23	...	...	...	...	...	...
Dragonne	F	TBD	119	81.4	2,897	1,400	25	...	...	...	...	...	...
Lancier	F	TBD	119	81.4	2,897	1 400	25	...	...	...	...	...	...
Grenadier	F	TBD	119	81.4	2,897	1,400	25	...	...	...	...	...	...
Chevalier	F	TBD	134	...	...	2 700	27	...	...	...	...	...	...
LAGRAFEL D'ALLEST.													
Bouvines	F	B S	6,505	...	...	9,250	17.5	...	...	...	...	...	...
Chas. Martel	F	B S	11,882	...	...	13,500	17.5	...	...	...	...	...	...
Carnot	F	B S	11,986	1,076	37,201	15,000	18	3,109	11.9	2.26	...	...	...
Deodoro	Brazil	B S	3,162	...	...	3,400	15	...	...	...	...	...	...
Floriano	Brazil	B S	3,162	...	...	3,400	15	...	...	...	...	...	...
Jemmapes	F	B S	6,487	646	21,647	9,250	17.5	...	...	...	...	...	...
Jaureguiberry	F	B S	11,824	1,085	35,092	13,000	17	7,965	15.8	1.51	3,386	12.25	1.54
Massena	F	B S	11,924	1,076.4	32,292	13,500	17	...	...	...	9,650	15.49	1.65
Valmy	F	B S	6,487	...	...	9,250	17.5	...	...	...	...	...	...
Cassard	F	P C	3,990	732	23,530	9,500	19.25	...	...	...	...	...	...
Chasseloup Laubat	F	P C	3,722	732	19,458	9,000	19.25	...	...	...	...	...	...
D'Assas	F	P C	3,990	732	23,530	9,500	19.5	3,500	16	1.52	8,000	18.7	1.82
Du-Chayla	F	P C	3,990	732	23,530	9,500	19.25	...	...	...	...	...	...
D'Iberville	F	TGB	925	...	...	5,000	21.5	...	...	...	...	...	...
Guichen	F	P C	8,277	...	...	24,000	23	...	...	...	...	...	...
Suchet	F	P C	3,427	...	...	9 000	20	...	...	...	...	16.7	...
Foudre	F	TDS	6,086	...	...	11,244	19	9,883	...	1.792	...	...	...
Kersaint	F	D B	1,243	...	...	2,200	15	...	...	...	...	...	...
Cuibianca	F	TGB	958	344	10,667	5,000	21	...	...	...	...	...	...
Cassini	F	TGB	958	344	10,667	5,000	21	...	...	...	...	...	...
Nadieja	Bulg	TGB	715	...	...	2,600	17	...	...	...	...	...	...
D'Estrees	F	P C	2,460	...	...	8,500	21	...	...	...	...	...	...
LAIRD.													
Express	B	TBD	427	310	17,020	9,250	33	...	...	...	...	...	...
Lively	B	TBD	332	202	12,000	6,000	30	...	...	...	...	...	...
Blanche	B	P C	1,580	...	...	3,000	16.5	...	...	...	...	...	...
Blonde	B	P C	1,580	...	...	3,000	16.5	...	...	...	...	...	...
Sprightly	B	TBD	332	202	12,000	6,000	30	...	...	...	...	...	...
NICLAUSSE.													
Henri IV	F	B S	8,948	...	...	11,500	17	...	...	...	...	...	...
Marceau	F	B S	10,581	...	...	12,000	16.4	...	...	...	...	...	...
Retvizan	R	B S	12,700	1,333.58	53,343.36	17,000	18	7,820	...	1.55	...	...	...
Reina Margherita	I	B S	13,500	1,550	50,312	19,000	20	...	...	...	...	...	...
Suffren	F	B S	12,728	1,130	42,000	16,200	18	...	...	...	...	...	...
Pelayo	S	B S	9,900	852	28,160	8,500	16	...	...	...	...	...	...
Maine	U S	B S	12,300	1,353	58,104	16,000	18	...	...	...	...	...	...
Georgia	U S	B S	14,600	...	...	19,000	19	...	...	...	...	...	...
Conde	F	A C	10,000	...	...	20,500	21	...	...	...	...	...	...
Cristobal Colon	S	A C	...	957.3	30,965	13,500	19.5	8,793	18 26	1.64	...	...	...
Gloire	F	A C	10,000	...	...	20,500	21	...	...	...	...	...	...
Gueydon	F	A C	9,516	...	...	19,000	21	...	...	...	...	...	...
Garibaldi	I	A C	7,400	1,090	35,217	13,500	19.5	...	...	...	9,812	16.12	...
Kleber	F	A C	7,700	1,100	35,500	17,100	21	...	...	...	...	...	...
Leon Gambetta	F	A C	12,416	...	...	27,500	22	...	...	...	...	...	...
Colorado	U S	A C	13,400	1,600	70,031	23,000	22	...	...	...	...	...	...
Virginia	U S	B S	14,600	1,459.6	57,534	19,000	19	...	...	...	...	...	...
Pennsylvania	U S	A C	13,400	1,600	70,031	23,000	22	...	...	...	...	...	...
Requin	F	B S	7,698	...	...	6,000	15	...	...	...	...	...	...
Emp. Alexander III.	R	B S	13,600	...	...	16,300	18	...	...	...	...	...	...
Suffolk	B	A C	9,800	...	...	23,000	23	...	...	...	...	...	...
Davout	F	P C	3,027	...	...	9,000	20.5	...	...	...	...	...	...
Freya	G	P C	6,100	775	25,850	10,000	18.5	...	...	...	...	...	...
Gazelle	G	P C	2,645	462	15,650	7,000	19.5	...	...	...	...	...	...
Pleurus	F	P C	1,310	...	...	4,000	18	...	...	...	...	...	...
Friant	F	P C	3,722	783	23,240	9,000	19.5	...	...	...	...	...	...
Variag	R	P C	6,500	1,575	622,290	20,000	23	...	...	...	...	...	...

Full power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq.ft. Grate.	IHP per sq.ft. Grate.	IHP per sq.ft heat	Air press.	
GUYOT-DU TEMPLE.							
28,130	...	2.002	34.2	17.10	.369	...	
...	...	...	...	...	...	...	
1,845	25	2.025	48.74	22.67	.637	...	Weight boiler installation, 27.38 tons.
1,845	25.79	2.025	48.74	22.67	.637	...	Weight boiler installation, 27.38 tons.
1,845	25.25	2.025	48.74	22.67	.637	...	Weight boiler installation, 27.38 tons.
...	27.2	...	...	...	...	...	
LAGRAFEL D'ALLEST.							
...	...	...	...	...	...	...	
14,791	18.13	1.78	...	...	...	...	
16,050	17.9	...	...	14.92	.451	...	Weight boiler installation, 591.45 tons.
...	14.87	...	...	...	...	...	
...	...	...	...	...	...	...	
9,106	...	2.137	30.1	14.10	.421	...	Weight boiler installation, 402.78 tons.
13,690	17.67	1.87	23.6	12.62	.39	...	Wt. machinery, 1,120 tons; fire-room weights, total, 551.7 tons.
13,460	17.09	1.94	24.25	12.50	.417	...	Weight of boilers, total, 439 tons.
...	...	...	...	...	...	...	
10,143	19.8	...	...	13.86	.431	...	Weight of machinery, 700 tons; boiler installation, 378.93 tons.
9,832	...	1.779	23 88	13.43	.505	...	Weight boiler installation, 373.28 tons.
9,500	19.8	1.865	24.2	12.98	.404	...	Weight of machinery, 700 tons; boiler installation, 378.93 tons.
10,005	20.2	...	...	14.30	.425	...	Weight of machinery, 700 tons; boiler installation, 378.93 tons.
5,060	...	...	...	...	...	...	
25,400	23.55	...	...	...	...	...	
...	20.41	...	...	...	...	...	
11,776	19.6	...	...	...	...	...	
...	...	...	...	...	...	...	
5,612	...	...	...	16.31	.526	...	
5,521	...	1.949	31.27	16.05	.518	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
LAIRD.							
8,722	30.916	2.29	64.42	28.13	.519	...	
6,456	30.278	2.38	76.06	31.96	.538	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
6,437	30.032	2.502	79.71	31.87	.536	...	
NICLAUSSE.							
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
18,300	17.95	1.8	24 69	13.72	.343	N D	
...	...	...	...	...	...	...	Weight of machinery, 1,603 tons.
...	...	...	...	...	...	...	
8,000	16	...	...	9.39	.284	N D	Weight boiler instal., 255 tons; floor space boiler inst., 1,222 sq.f.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
10,671	19 35	...	...	11.15	.344	N D	Weight boilers, water, smoke pipes, 370.6 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
14,511	19 66	...	...	13 31	.409	.51	Weight of machinery, 1,087 tons.
...	...	...	...	...	...	...	Weight of engines, 663 tons; weight of boilers, 612 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
19,500	20	...	...	13.06	.379	...	Weight of boiler installation, 398.6 tons.
6,275	...	...	...	13.	.39	...	
...	...	...	...	...	...	...	
9,438	...	2 036	24.53	12.05	.406	...	Weight of boiler installation, 363.19 tons.
...	...	...	...	...	...	...	

Name.	Nation	Type	Displacement	Boilers.		Designed.		Coal consumption at moderate speed.			Continuous full-power trial. Natural draft.		
				Grate surface	Heating surface	IHP	Speed	IHP	Speed	Coal per IHP	IHP	Speed	Coal per IHP
Merlin	B	Sloop	1,070	...	...	1,400	13.25	...	...	...	...	...	...
Nevada	U S	M	3,235	220	8,876	2,400	11.5	...	...	...	...	...	...
Sarmiento	Arg	P C	2,750	...	...	2,000	13	...	...	...	...	...	...
Decidee	F	G B	646	...	...	900	13	300	...	1 51	500	...	1.80
Khrabry	R	G B	1,500	223.9	6,786	2 000	14	...	...	...	...	...	...
Zelee	F	G B	646	...	...	900	13	335	...	1.26	550	1.60	...
Seagull	B	T G B	735	...	...	3,500	19	1,350	...	1.87	1,600	...	1.70
NORMAND.													
Bogatyr	R	P C	6,395	...	...	19 500	23	...	...	...	...	...	...
Infernet	F	P C	2,460	...	...	8,500	21	...	...	...	...	...	...
Petrel	B	T B D	...	...	...	6,200	30	...	...	...	...	...	...
Pelorus	B	P C	2,135	350	15,856	7,000	20	3,559	.78‡	2.20	5,379	1.7‡	...
Rainha Amelia	P	P C	1,660	...	...	4.500	17.5	...	...	...	3,088	17.1	...
Yatagan	F	T B D	304	...	...	5.700	27	...	...	...	...	...	...
New Cruiser	R	P C	6,250	988.8	49,496	19,500	23	...	...	...	...	...	...
Ad. Simpson	Chili	T G B	858	...	...	4.500	21	...	...	...	...	...	...
Thompson	Chili	T B	130	...	...	2,000	25.5	...	...	...	...	...	...
Rodriquez	Chili	T B	130	...	...	2,000	25.5	...	...	...	...	...	...
Brazen	B	T B D	318	224	12,000	6,000	30	...	...	...	...	...	...
Duranda	F	T B D	...	...	...	4,800	26	...	...	...	...	...	...
Earnest	B	T B D	360	...	...	6.000	30	...	...	...	...	...	...
Electra	B	T B D	319	224	12,000	6,000	30	...	...	...	...	...	...
Griffon	B	T B D	360	...	...	6,000	30	...	...	...	...	...	...
Fauconneau	F	T B D	...	...	...	5,700	26	...	...	...	...	...	...
Hallebarde	F	T B D	...	...	...	4,800	26	...	...	...	...	...	...
Panther	B	T B D	360	...	...	6,000	30	...	...	...	...	...	...
Quail	B	T B D	360	...	...	6,000	30	...	...	...	...	...	...
Recruit	B	T B D	324	224	12,000	6,000	30	...	...	...	...	...	...
Thrasher	B	T B D	360	...	...	6,000	30	...	...	...	...	...	...
Thorn	B	T B D	342	224	12,562	6,000	30	...	...	...	...	...	...
Tiger	B	T B D	339	224	12,562	6,000	30	...	...	...	...	...	...
Virago	B	T B D	360	...	...	6,000	30	...	...	...	...	...	...
Vigilant	B	T B D	338	224	12,562	6,000	30	...	...	...	...	...	...
Wolf	B	T B D	360	...	...	6,000	30	...	...	...	...	...	...
No. 201	F	T B D	80	45	2,120	1,500	24	...	...	...	...	...	...
No. 202	F	T B D	80	45	2,120	1,500	24	...	...	...	...	...	...
No. 203	F	T B D	80	45	2,120	1 500	24	...	...	...	...	...	...
No. 204	F	T B D	80	45	2,120	1.500	24	...	...	...	...	...	...
No. 205	F	T B D	80	45	2,120	1 500	24	...	...	...	...	...	...
Nos. 230, 232	F	T B D	85	...	...	1,500	24	...	...	...	...	...	...
Vixen	B	T B D	360	234	12,000	6,000	30	...	...	...	...	...	...
Orella	Chili	T B D	300	...	...	6,000	30	...	...	...	...	...	...
Nos. 148, 140, 152, 153	F	T B	79	35.7	1,894	1,300	24	...	...	...	...	...	...
Nos. 182, 185	F	T B	80	36.7	1,839	1,300	24	...	...	...	...	...	...
Munoz Gamero	Chili	T B D	300	...	...	6,000	30	...	...	...	...	...	...
Serrano	Chili	T B D	300	...	...	6,000	30	...	...	...	...	...	...
Riquelme	Chili	T B D	302	...	...	6,000	30	...	...	...	...	...	...
NORMAND-SIGAUDY.													
Montcalm	F	A C	9,516	...	...	19,600	21	...	...	1.48	...	...	...
Chateaurenault	F	P C	8,018	1,362	64,130	23,000	23	...	...	...	18,400	21.9	1.4
Espignole	F	T B D	300	...	...	...	...	4,800	26	...	...	...	...
Dunois	F	T B D	896	...	...	...	...	6,400	23	...	...	...	...
La Hire	F	T G	896	...	...	...	...	6,400	23	...	...	...	...
REED.													
Pyramus	B	P C	2,135	360	18,876	7,200	20	3,605	17.49	2.05	5,424	19 9	...
Pegasus	B	P C	2,135	360	18,876	7,000	20	3,698	.4‡	1.96	5,400	.86‡	...
Myrmidon	B	T B D	345	257.8	13,498	6.200	30	...	...	...	...	...	...
Kangaroo	B	T B D	346	257.8	13,498	6,200	30	...	...	...	...	...	...
Bat	B	T B D	360	...	...	5.900	30	...	...	...	...	...	...
Chamois	B	T B D	360	...	...	5,900	30	...	...	...	...	...	...
Crane	B	T B D	360	...	...	5.900	30	...	...	...	...	...	...
Flying Fish	B	T B D	360	...	...	5.900	30	...	...	...	...	...	...
Petrel	B	T B D	340	258	13,784	6,200	30	...	...	...	...	...	...
Star	B	T B D	360	...	...	5,900	30	...	...	...	...	...	...

‡ Air pressure.

Full power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq. ft. Grate.	IHP per sq. ft. Grate.	IHP per sq. ft heat	Air press.	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	13.5	...	...	...	...	...	
900‡	13	1.8	...	...	...	...	
2,200	...	1.68	15.01	9.82	.324	...	Total weight boiler installation, 105.5 tons.
953	13.5	1.586	...	...	...	...	
3,546	...	2.3	...	...	...	...	
NORMAND.							
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
6,438	...	...	...	...	...	...	
7,094	20 73	...	...	20.08	.444	4.3	Weight of machinery, 382 tons; boilers, complete, 169 tons.
5,396	20.6	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
6,539	29.565	2.5	72.98	29.19	.545	...	
...	...	...	...	...	...	...	
6,366	30.04	2.41	..	...	...	...	
6,567	29 56	2.32	68.02	29.32	.547	...	
6,268	30.019	2.53	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
6 606	30 11	2.43	...	...	...	...	
6,003	30.039	...	...	...	...	...	
6,581	29 319	2.33	68.46	29.38	.548	...	
6,562	29 78	2 67	...	...	...	...	Strong wind and sea.
6,540	30 174	2.34	68.30	29.19	.517	...	
6,840	29.921	2 34	71 44	30.53	.541	...	
6,425	30.07	2.42	...	...	...	...	
6,218	30.09	2.38	66.07	27 76	.491	...	
...	30 114	...	...	...	...	...	
1,920	25 703	1.45	61.77	42.67	.906	...	
1,920	25 703	1.45	61.77	42 67	.906	...	Average of five boats.
1,920	25.703	1.45	61.77	42.67	.906	...	
1,920	25.703	1.45	61.77	42.67	.906	...	
1,920	25.703	1.45	61.77	42.67	.906	...	
...	...	...	...	...	...	...	
6,758	29.389	2.41	69.60	28.88	.563	...	
...	30.17	...	...	...	...	...	
1,176	...	1.982	67.85	32.94	.329	...	Weight boiler installation, 15 21 tons.
1,599	...	1.65	68.11	41.32	.869	...	Weight boiler installation, 16.085 tons.
...	30.4	...	...	...	...	...	
...	30.3	...	...	...	...	...	
...	30.12	...	...	...	...	...	
NORMAND-SIGAUDY.							
20,378	20.3	...	...	...	...	...	
22,500	...	1.84	30.7	16.67	.354	...	Weight boiler installation, 793.40 tons.
...	...	...	...	...	...	...	
...	21.7	...	...	...	...	...	
...	...	...	...	...	...	...	
REED.							
7,303	20.7	...	...	23.06	.387	...	Weight, complete, machinery, 360 tons; boilers, 159 tons, specif.
7,134	21.20	...	...	19.82	.378	2.44	Weight, complete, machinery, 378 tons; boilers, 185 tons, built.
6,601	30 134	2.20	56.33	25.6	.489	...	
6,488	30.184	2.26	56 89	25.17	.481	2.8	
6,209	30.229	2.59	...	...	...	3	
6,265	30,396	2.42	...	...	...	2.75	
6,428	30.138	...	...	...	...	...	
6,200	30.288	...	...	...	...	...	
6,444	30.097	2.3	57.43	24.97	.467	...	
6,197	30.103	2.64	...	...	...	...	

‡ Estimated.

Name.	Nation	Type	Displacement	Boilers.		Designed.		Coal consumption at moderate speed.			Continuous full-power trial. Natural draft.		
				Grate surface	Heating surface	IHP	Speed	IHP	Speed	Coal per IHP	IHP	Speed	Coal per IHP
Spiteful	B	T B D	360	...	...	5,900	30.3	...	...	....	...	...	...
Whiting	B	T B D	360	...	...	5,900	30.	...	...	....	...	...	...
Zephyr	B	T B D	236	238	9,936	3,800	27	...	...	....	...	...	...
Syren	B	T B D	353	257.8	13,498	6,200	30	...	...	....	...	...	...
Pervent	B	T B D	280	...	...	3,800	27	...	...	....	...	...	...
Fawn	B	T B D	360	...	...	5,900	30	...	...	....	...	...	...
Skipjack	B	T G	735	...	...	6,000	20.5	1,222	14.4	1.6	...	...	...
Flirt	B	T B D	360	...	...	5,900	30	...	...	....	...	...	...
Janus	B	T B D	280	...	...	3,800	27	...	...	....	...	...	...
Lightning	B	T B D	280	...	...	3,800	27	...	...	....	...	...	...
Porcupine	B	T B D	280	...	...	3,800	27	...	...	....	...	...	...
Speedwell	B	G B	735	286.9	13,504	6,000	20.5	...	...	....	....	...	...
SCHICHAU.													
Novik	R	P C	3,000	...	...	17,000	25	...	...	....	...	...	...
ORIOLLE.													
Nos. 161, 162, 163	F	T B	79	48.4	1,705	1,300	21	...	...	....	...	...	...
Zouave	F	S T B	119	62.8	2,196	2,400	21	...	...	....	...	...	...
SCHULTZ.													
Askold	R	P C	6,500	...	...	19,000	23	...	...	....	....	...	...
Amazone	G	P C	2,645	488	25,000	8,000	21	...	...	....	....	...	...
Ariadne	G	P C	2,645	488	25,000	8,000	21	...	...	....	....	...	...
Medusa	G	P C	2,645	488	25,000	8,000	21	...	...	....	....	...	...
Nymphe	G	P C	2,645	488	25,000	8,000	21	3,448	...	1.67	....	...	...
Thetis	G	P C	2,645	488	25,000	8,000	21	...	...	....	....	...	...
Wurtemberg	G	B S	7,400	412	22,500	7,000	17	3,990	...	2.23	4,384	...	2.51
THORNYCROFT.													
Ægir	G	B S	3,495	274	16,150	5,000	16	1,325	...	2.15	3,632	...	1.69
Hagen	G	B S	3,495	...	...	4,800	15	...	...	....	....	...	...
Illus	G	G B	895	81.8	4,098	1,300	13.5	896	...	1.99	1,272	...	1.60
Jaguar	G	G B	895	81.8	4,098	1,300	13.5	876	...	1.84	1,250	...	1.69
Tiger	G	G B	895	81.8	4,098	1,300	13.5	1,145	...	3.31	1,146	...	2.79
Luchs	G	G B	895	81.8	4,098	1,300	13.5	463	...	2.9	1,104	...	2.12
Bellona	B	P C	1,830	...	...	4,700	19	...	...	....	4,250	19.1	...
Barham	B	P C	1,830	...	...	4,700	19	...	...	....	4,500	18.6	...
Niobe	G	P C	2,645	420	21,740	8,000	21	...	...	....	....	...	...
Perseus	B	P C	2,135	355.2	17,750	7,000	20	3,627	17.2	2.10	5,243	18.9	2.26
Prometheus	B	P C	2,135	355.2	17,750	7,000	20	3,572	17.5	2.01	5,187	19.8	2.30
Pioneer	B	P C	2,135	355.2	21,152	7,000	20	3,665	16.3	2.2	5,263	17.7	...
Pandora	B	P C	2,135	355.2	21,152	7,000	20	3,644	16.7	2.11	5,218	...	...
Psyche	B	P C	2,135	350	20,508	7,000	20	3,646	16.8	2.301	5,098	19.3	2.44
Proserpine	B	P C	2,135	348.75	20,508	7,000	20	3,644	.53‡	2.40	5,336	.94‡	2.47
Chihaya	J	P C	1,250	...	...	6,000	21	...	...	....	....	...	...
Veloce	F	S G T	114	76	4,126	1,550	23.6	...	...	....	...	...	...
Charger	B	T B D	250	177.6	8,520	3,100	26	...	...	....	....	...	...
Hasty	B	T B D	250	177.6	8,520	3,100	26	...	...	....	....	...	...
Albatross	B	T B D	383	252	16,020	7,500	32	...	...	....	....	...	...
Angler	B	T B D	310	...	...	5,400	30	...	...	....	....	...	...
Bulfinch	B	T B D	320	237	13,050	5,800	29	...	...	....	....	...	...
Coquette	B	T B D	355	...	...	5,400	30	...	...	....	....	...	...
Cheerful	B	T B D	355	...	...	5,800	30	...	...	....	....	...	...
Dove	B	T B D	324	237	13,050	5,800	29	...	...	....	....	...	...
Foam	B	T B D	310	...	...	5,400	30	...	...	....	....	...	...
Falcon	B	T B D	333	245	13,000	6,250	30	...	...	....	....	...	...
Fume	B	T B D	310	...	...	5,700	30	...	...	....	....	...	...
Lee	B	T B D	335	237	13,520	6,000	30	...	...	....	....	...	...
Mermaid	B	T B D	355	...	13,200	6,000	30	...	...	....	....	...	...
Gipsy	B	T B D	355	...	...	6,000	30	...	...	....	....	...	...
Mallard	B	T B D	310	...	...	5,400	30	...	...	....	....	...	...
Magnet	B	T B D	...	...	...	6,000	26	...	...	....	....	...	...
Osprey	B	T B D	355	...	...	6,000	30	...	...	....	...	...	...

‡ Air pressure.

Full power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq.ft. Grate.	IHP per sq.ft. Grate.	IHP per sq.ft heat.	Air press.	
...	...	2.3	...	...	...	...	
6,254	30.167	2.76	...	...	...	...	
3,885	27.171	...	...	16.32	.391	...	
6,665	29.764	2.49	64.37	25.85	.494	...	
3,850	27	...	...	...	...	...	
...	30.2	...	...	...	...	...	
6,089	20.258	...	...	...	...	...	
...	...	...	...	...	...	...	
3,900	27.8	...	...	...	...	...	
3,900	27.9	...	...	...	...	...	
3,900	27.9	...	...	...	...	...	
6,062	20.8	...	...	21.13	.449	...	
SCHICHAU.							
...	...	...	...	...	...	...	
ORIOLLE.							
...	...	...	...	...	...	...	Weight boiler installation, 16.5 tons.
...	...	...	...	...	...	...	Weight boiler installation, 22.48 tons.
SCHULTZ.							
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
8,897	22.18	2.08	37.63	18.09	.353	1.69	
...	...	...	...	...	...	...	
8,375	...	...	...	17.1	.334	...	
8,888	21.7	...	...	18.21	.355	...	
6,177	...	...	...	15	.274	...	
THORNYCROFT.							
4,048	...	...	...	18.06	.307	1.3	Weight boiler installation, 190.53 tons.
...	...	...	...	...	...	...	
1,358	...	...	...	16.6	.331	...	
1,358	...	...	...	16.6	.331	...	
1,325	...	...	...	16.2	.324	...	
1,351	...	...	...	16 5	.331	...	
6,035	19.75	...	...	...	...	...	
6,152	19	...	...	...	...	...	All weights on board when tried.
8,000	...	...	...	19.2	.369	...	
7,069	20	...	...	19.9	.398	2.39	Weight, complete, machinery, 365 tons; boilers, 165 tons.
7,275	20.8	...	...	20.48	.410	2.58	Weight, complete, machinery, 360 tons; boilers, 156 tons, specif.
7,185	19.175	2.45	49.55	20.23	.340	...	
7,330	19.18	2.33	48.07	20.63	.346	...	
7,005	21	...	...	20.02	.342	2.7	Weight, complete, machinery, 360 tons; boilers, 165 tons, specif.
7,143	...	3.16	64 72	20.48	.348	2.9	Weight, complete, machinery, 409 tons; boilers, 172 tons.
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	Weight boiler installation, 27.14 tons.
3,746	25.33	...	...	21.09	.4396	...	
3,822	25.59	...	...	21.52	.4485	...	
7,732	31.552	2.26	69.34	30.68	.483	...	
5,820	30.372	...	...	...	...	...	
6,022	29.46	2.37	60.48	25.52	.461	...	
5,868	30.211	...	...	...	...	2.72	
...	...	...	...	...	...	...	
5,802	29.25	2.75	67.49	24.54	.444	...	
5,846	30.09	2.23	...	...	...	...	
6,299	30.135	2.22	57.08	25.71	.484	...	
5,912	30.10	2.595	...	...	...	4	
6,558	30.11	2.535	70.14	27.67	.485	...	
6,541	30.8	...	...	...	.495	...	
...	30.207	...	...	...	...	...	
5,746	30.201	2.08	...	...	...	...	
5,946	...	2.23	...	...	...	...	
6,568	30.674	2.58	...	...	...	4.5	

Name.	Nation	Type	Displacement	Boilers.		Designed.		Coal consumption at moderate speed.			Continuous full-power trial. Natural draft.		
				Grate surface	Heating surface	IHP	Speed	IHP	Speed	Coal per IHP	IHP	Speed	Coal per IHP
Ostrich	B	T B D	331	245	13,000	6,250	30	...	...	...	...	...	...
Stag	B	T B D	306	193	12,072	5,000	30	...	...	...	...	...	...
No. 98	B	T B	181	104	6,080	2,800	25	...	...	...	...	...	...
No. 99	B	T B	185	104	6,080	2,800	25	...	...	...	...	...	...
No. 107	B	T B	184	104	6,080	2,800	25	...	...	...	...	...	...
No. 108	B	T B	182	104	6,080	2,800	25	...	...	...	...	...	...
Missouri	U S	B S	12,230	1,000	51,372	16 000	18	...	...	...	...	...	...
Ohio	U S	B S	12,440	924	53,253	15,100	18	...	...	...	...	...	...
Arkansas	U S	M	3,235	198	9,370	2,400	12	...	...	...	...	...	...
Dale	U S	T B D	420	315	17,768	8.000	28	...	...	...	...	...	...
Decatur	U S	T B D	420	315	17,768	8,000	28	...	...	...	...	...	...
Hopkins	U S	T B D	408	294	17,612	7.200	29	...	...	...	...	...	...
Hull	U S	T B D	408	294	17,612	7 200	29	...	...	...	...	...	...
Paul Jones	U S	T B D	420	315	17,783	8,000	28	...	...	...	...	...	...
Perry	U S	T B D	420	315	17,783	8,000	28	...	...	...	...	...	...
Preble	U S	T B D	420	315	17,783	8,000	28	...	...	...	...	...	...
Truxtun	U S	T B D	433	315	17,768	8 300	28	...	...	...	...	...	...
Whipple	U S	T B D	433	315	17,768	8,300	28	...	...	...	...	...	...
Worden	U S	T B D	433	315	17,768	8,300	28	...	...	...	...	...	...
Stringham	U S	T B	340	252	16,020	5,850	30	...	...	...	...	...	...
Goldsborough	U S	T B	247.5	216	13,500	5,600	30	...	...	...	...	...	...
Tingey	U S	T B	167	137	7 548	3,000	26	...	...	...	...	...	...
YARROW.													
Norge	N	B S	3,850	...	...	4,500	16.5	...	...	...	...	...	...
Corrientes	Arg	T B D	280	...	...	4,200	26	...	...	...	...	...	...
Du Ruyter	H	A C	4,950	...	...	6,000	16	...	...	...	...	...	...
Koningen Regentes	H	A C	4,950	...	...	6,000	16	1,710	11.85	3.13	3,081	14 2	2 44
Santa Fe	Arg.	T B D	280	...	...	4,200	26	...	...	...	...	...	...
Aspern	A	P C	2,437	350	20,700	7,200	20	...	...	...	...	...	...
Don Carlos	P	P C	4,280	587	32,000	12,500	22	...	...	...	...	...	...
Gelderland	H	P C	4,033	...	...	10,000	20	...	...	...	...	...	...
Nord Brabant	H	P C	4,033	456	25,720	10,000	20	...	...	...	...	...	...
Utrecht	H	P C	4,033	...	...	10,000	20	...	...	...	...	...	...
Szigetvar	A	P C	2,437	350	20,000	8,000	20.5	...	...	...	...	...	...
Zenta	A	P C	2,300	350	20,000	7,200	20	...	...	...	...	...	...
(a) *Tupperheten*	Sw	A C D	3,650	376.8	15,610	6,000	17	...	...	...	...	...	...
(b) *Vasa*	Sw	A C D	3,650	376.8	15,610	6,000	17	...	...	...	...	...	...
(c) *Aran*	Sw	A C D	3,650	376 8	15,610	6,000	17	...	...	...	...	...	...
Dristigheten	Sw	A C D	3,450	376.8	15,610	6,000	17	...	...	...	...	...	...
Eidsvold	N	A C D	3,850	...	...	4 500	16.5	...	...	...	...	...	...
Nordh	Sw	A C D	3,300	...	...	3.650	16	...	...	...	...	...	...
Thor	Sw	A C D	3,300	...	...	3.650	16	...	...	...	...	...	...
Greyhound	B	T B D	340	252	13,200	6,000	30	...	...	...	...	...	...
Akebono	J	T B D	3.6	...	...	6,000	31	...	...	...	...	...	...
Hiwock	B	T B D	240	150	8,512	3,000	26	...	...	...	...	...	...
Inadsuma	J	T B D	306	...	...	6,000	31	...	...	...	...	...	...
Ikadsuchi	J	T B D	306	...	...	6 000	31	...	...	...	...	...	...
Niji	J	T B D	306	...	...	6,000	31	...	...	...	...	...	...
Oooro	J	T B D	306	...	...	6,000	31	...	...	...	...	...	...
Sizanami	J	T B D	306	...	...	6,000	31	...	...	...	...	...	...
Spitfire	B	T B D	295	178	8,500	4.500	27	...	...	...	...	...	...
Swordfish	B	T B D	295	178	8,500	4.500	27	...	...	...	...	...	...
Rochuck	B	T B D	335	252	13,200	6 000	30	...	...	...	...	...	...
Racehorse	B	T B D	335	252	13,200	6,000	30	...	...	...	...	...	...
Bramble	B	G B	710	80	4,000	1,300	13.5	661	10.85	2.32	940	11.10	2.4
Britomart	B	G B	710	80.5	4,002.2	1,300	13.5	667	11.2	...	957	13	2.52
Dwarf	B	G B	710	80	4,000	1,300	13.5	687	11.6	2.22	966	13.1	...
Thistle	B	G B	710	80	4,000	1,300	13.5	696	11.5	2.13	966	12 93	2.09
Azrahan	H	G B	...	...	...	...	...	215	8.5	3.13	806	12 30	2.08
Misiones	Arg	T B D	280	...	...	4,200	26	...	...	...	...	...	...
Entre Rios	Arg	T B D	280	...	...	4,200	26	...	...	...	...	...	...
Hertog Hendrick	H	A C D	3,650	376.8	15,610	6 000	17	...	...	...	...	...	...
Manligheten	Sw	A C D	3,650	376.8	15,610	6,000	17	...	...	...	...	...	...
E	A	P C	7,400	...	...	13,000	21	...	...	...	...	...	...
A, B, C	A	A C D	10,600	...	...	14,000	19	...	...	...	...	...	...

Full power trial.							
IHP	Speed	Coal per IHP	Coal per sq. ft. Grate.	IHP per sq. ft. Grate.	IHP per sq. ft heat.	Air press.	Remarks.
6,311	30.113	2.206	56 83	25 76	.486	...	
5,204	30.156	2.307	62.20	26.96	.431	...	
2,883	24.982	2.44	67.62	27.72	.474	...	
2,(67	25.069	2 59	66.41	25.6:	.439	...	
2,823	25.053	2 325	63.13	27.15	.464	...	
2,876	25.359	2.009	55.55	27 66	.473	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
YARROW.							
...	...	...	...	...	...	...	
...	27.4	...	...	...	...	...	
...	...	...	...	...	...	...	
7,291	16.91	2 09	...	...	...	...	
...	27.13	...	...	...	...	1.75	
...	...	...	...	...	...	...	
12,690	22.15	...	...	21.62	.396	...	Rough sea, strong wind. Total fire-room weights, 329 tons.
...	...	...	...	...	...	...	
10,067	20.1	2.05	45.26	22.08	.391	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
7,990	20.89	...	...	22.83	.3995	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	17	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
6,368	30.157	2.345	58.86	25.27	.483	...	
...	...	...	...	...	...	...	
3,713	26.7	...	...	24.75	.436	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	1.98	52.3	...	...	.9	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
4,506	27.46	...	...	25.31	.530	3.09	Weight of machinery, 46.63 tons.
4,570	27.117	...	...	25.67	.538	2.3	Weight of machinery, 46.63 tons.
6,537	30.34	2.38	61.7;	25.94	.495	...	
6,292	30.179	2.378	59 37	24.97	.477	...	
1,360	13.38	2 60	44.2	17	.340	...	
1,378	14.6	...	...	17.12	.344	1.2	
1,401	14 15	2.46	43.07	17.51	.350	...	
1,352	13.5	2.47	41 74	16.90	.338	.75	
1,353	13 95	2.12	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	
...	...	...	...	...	...	...	

Name.	Nation	Type	Displacement	Boilers.		Designed.		Coal consumption at moderate speed.			Continuous full-power trial. Natural draft.		
				Grate surface	Heating surface	IHP	Speed	IHP	Speed	Coal per IHP	IHP	Speed	Coal per IHP
CYLINDRICAL AND WATER TUBE.													
K. Wilh. de Grosse....	G	B S	11,130	465*	23,250* 16,900†	13,000	18	...	...	...	...	...	...
K. Karl de Grosse.....	G	B S	11,130	...	...	13,000	18	...	...	...	...	...	...
K. Friedrich III.....	G	B S	11,130	655†	23,280†	13,000	18	...	...	...	12,860	...	1.84
K. Wilhelm II.....	G	B S	11,130	280‡	13,250‡	13,000	18	...	...	...	...	...	1.82
K. Barbarossa.....	G	B S	11,130	...	...	13,000	18	...	...	...	...	...	...
Schwaben.....	G	B S	12,000	505.92†	16,792†	13,000	18	...	...	...	7,360	15.5	1.84
Wittelsbach.....	G	B S	12,000	413.35*	23,929*	15,000	19	...	...	...	...	...	...
Wettin.....	G	B S	12,000	...	41,873	15,000	19	...	...	...	...	...	...
Furst Bismark.....	G	A C	10,650	...	41,873	15,000	19	...	...	...	...	...	...
				655†	23,500	14,000	19	...	...	...	...	...	...
				327*	17,450								
Friesland.....	H	P C	3,900	322*	16,140*	10,000	20	...	...	...	...	...	...
				126†	4,005†								
Holland.....	H	P C	3,900	322*	16,140*	10,000	20	...	...	...	...	...	...
				126†	4,005†								
Zeeland.....	H	P C	3,900	322*	16,140*	10,000	20	...	...	...	...	...	...
				126†	4,005†								
Atlanta.....	U S	P C	3,000	212*	7,800*	3,500	15	710.6	9	2.3	1,895	12.07	2.17
				91†	3,024.58†								
Chicago.....	U S	P C	4,500	259.2*	14,700*	9,000	18.5	1,912	10	2.05	3,828	14.66	2.03
				373.2†	8,552.6†								
Monterey.....	U S	MON	4,000	295.2*	11,880.0*	5,000	13.5	...	...	...	...	...	...
				88†	2,905.08†								

* Water tube. † Cylindrical. ‡ Tubular.

Full-power trial.							Remarks.
IHP	Speed	Coal per IHP	Coal per sq.ft. Grate.	IHP per sq.ft. Grate.	IHP per sq.ft. heat.	Air press.	
CYLINDRICAL AND WATER TUBE.							
...	...	...	...	...	...	...	⅛ Shultz.
...	...	...	...	...	...	...	⅛ Shultz.
13,500	18	...	...	...	...	...	⅛ Thornycroft. Weights, cyl., 593 tons; tub., 154 tons.
...	...	...	...	...	...	...	⅛ Shultz.
13,940	18	...	...	15.16	.342	2.05* .45†	⅛ Thornycroft.
...	...	...	...	...	...	...	⅛ Shultz.
...	...	...	...	...	...	...	⅛ Shultz.
...	...	...	...	...	...	...	⅛ Shultz.
13,420	...	...	...	13.7	.328	...	⅛ Shultz. Weight boilers, 785 tons.
10,416	20	1.727	40.15	23.25	.517	1.25	⅓ Yarrow. Weight all machinery, 600 tons.
...	...	...	...	...	...	...	⅓ Yarrow. Weight all machinery, 600 tons.
...	...	...	...	...	...	...	⅓ Yarrow. Weight all machinery, 600 tons.
...	...	...	...	...	...	...	2 cyl. and 4 B. & W. boilers.
...	...	...	...	...	...	...	4 cyl. and 6 B. & W. boilers.
5,244	13.6	...	...	13.68	.359	3.2	4 Ward. 2 s. e. cyl. Weight of boiler installation, 141.384 tons.

* Water tube. † Cylindrical.

NOTES.

CORROSION OF BOILER TUBES.

Prepared from a report made by Lieutenant W. H. Chambers, U. S. Navy.

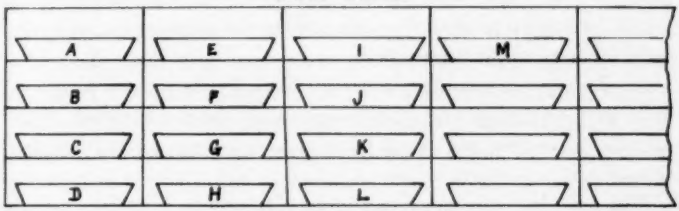
On January 18, 1901, the Bureau of Steam Engineering of the Navy Department drew up a letter directing the Naval Inspector of Engineering Material for the Pittsburg District to carry out a series of tests in order to ascertain the relative corrodibility of lap-welded Bessemer steel, lap-welded iron, seamless cold-drawn steel, and seamless hot-drawn steel boiler tubes. All of the samples were to be obtained from the same company. The letter also contained instructions as to the method of carrying out the experiments.

The National Tube Company not only generously offered the use of their laboratory at McKeesport, but also offered to bear the expense of installing the necessary apparatus, to furnish the sample tubes, to assist in conducting the tests, and to direct their photographer to make the necessary photographs by which to illustrate the nature of the corrosion.

The Bureau's letter directed the tests to be made in twelve tanks, each tank to contain sixteen samples, and samples from the top, middle and bottom of the steel ingots to be placed in the same tank. It further directed that the samples be shifted in their position each week, so that at the end of a period of sixteen weeks each sample should have occupied consecutively every position in the tank in which it was placed, and at the end of each such period the samples to be taken from the tanks, cleaned with a brush but not scraped, washed, dried, weighed and photographed, the results tabulated and forwarded to the Bureau, together with the photographs and a report. The report upon which this article is based is that made at the expiration of the first sixteen weeks.

Owing to the necessary delay incident to the installation of the apparatus, the securing of material for and the manufacture of the test tubes, the tests did not begin until July 2, 1901. They were carried on in a room adjoining the chemical laboratory of the National Tube Company, the twelve tanks necessary being fitted against the wall on one side of the room, in three vertical rows of four tanks each, the tanks being lettered as shown by the following sketch of their arrangement:

SKETCH NO. 1.



ARRANGEMENT OF TANKS.

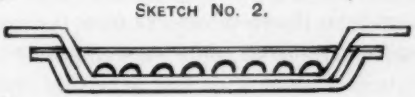
The tanks were porcelain lined, to guard against corrosion, and were partly filled with water, the water level in the lowest row being about twelve inches above the floor, and in each of the other rows about eighteen inches above that next below.

Additional tanks were also fitted to allow the metallurgist of the company to carry on other tests under conditions differing from those defined in the Bureau's letter of instructions.

A Westinghouse vertical air compressor was secured to the wall of the room, near the window, and the suction pipe led to the outside air in order to secure a supply of air as pure as possible.

Four glass pipes, bent as shown in sketch No. 2, with small holes one inch apart along their upper sides, and closed at one end, were placed in the bottom of each tank and connected at their open ends by rubber tubes to stopcocks, for regulating the supply of air.

SKETCH NO. 2.



It was found impracticable to connect all these tubes with the air compressor by a system of glass and rubber tubes and glass stopcocks, as was required by the instructions, so iron pipes were used, no parts of which, however, were in the water in the tanks.

The air supply was ample and continuous, and was easily regulated by the stopcocks, so that at no time could any water have been drawn back into the pipes from the tanks. The installation of the iron pipes, instead of the glass and rubber tubes required, is not believed to have had any influence upon the results obtained. Only twice during the period of sixteen weeks was it found necessary to stop the compressor for adjustment, and then only for very short intervals.

In placing the sample pieces in the tanks they were so placed as to rest on two of the glass tubes, with about one-third of the sample projecting over each tube, thus insuring a good distribution of air.

The samples were made six inches in length, from tubes made especially for the purpose, and were all the same diameter, three inches outside, and the same gauge, No. 9 B.W.G.

The lap-welded tubes were all made from the same ingot. After the usual discard was made the slabs from the ingot were numbered consecutively, number one slab being next to the discard from the top of the ingot.

The tubes were subjected to the same physical tests as required for boiler tubes. The test pieces were examined for surface defects, and those that would not have passed this inspection for boiler tubes were not used in the tests.

After this weeding out, from those remaining the necessary number were taken from as near as possible to the top, the middle and the bottom of the ingot. In the column "No. of sample," in the table for lap-welded tubes appended, the first figure indicates the slab number, and the second figure the tube number from that slab. The appended tables are not the full tables given in the report, but from each tank are given the results obtained from the steel samples from the top, middle and bottom of ingots respectively, showing the least and the greatest

amount of corrosion, and for the charcoal-iron samples, the samples from each tank showing the least and the greatest amounts of corrosion. Cuts showing the best and the worst of the sample tubes of each class of tubes after their sixteen weeks' immersion, are also appended to this article. The tables giving a recapitulation and average of the results obtained, cover the entire set of sample tubes experimented upon. In the original tables care was taken to mark by an "X" those samples which were the half of the tube containing the weld, the weld being left in the middle line of the sample to ascertain if it would affect the relative corrodibility of the metal.

In some cases the two halves of the same tube sample were not used, one half being rejected for surface defects, as, for the purposes of the experiment, as has been before stated, it was deemed best to take the samples from as near the top, middle and bottom of the ingot as possible, after rejecting the defective pieces.

The identifying numbers were stamped into both the convex and the concave sides of the samples to insure that they would not be effaced by corrosion, and were examined from time to time during the experiment to ascertain if they were still legible.

For the purpose of the photographer a simpler system of identification was used. Labels were pasted on the tubes, the letter of the tank and consecutive numbers from 1 to 16 being used. These photograph numbers and letters were entered in their proper column in the tables—the tables connecting the two different systems of numbering.

According to instructions, each tank containing steel tubes was filled with samples from the tops, middles and bottoms of the ingots, in order to insure that tubes from these three locations would be acted upon by exactly the same influences.

Thirty-three billets from the same ingot, each 16 inches long and $4\frac{1}{2}$ inches in diameter, so marked as to identify the locality, top, middle or bottom, of the ingot from which it was taken, and its relative position in that location, were supplied by the Pennsylvania Steel Company from which to make the seamless-drawn tubes. Of these billets the first six from each location were used

for the manufacture of the cold-drawn tubes, and the remainder for the hot-drawn.

The cold-drawn tubes were made in the usual manner, by hot piercing, hot swedge rolling, and cold drawing. In the column, "No. of sample," *T*, *M*, and *B* indicate what portion of the ingot the billet was taken from. The figures next to these letters indicate the number of the billet. The next letters, *P* and *O*, indicate whether the sample came from the pointed or open end of the tube as drawn, as it was found necessary to take two samples from each tube on account of the small number of billets supplied. In the case of these tubes the "X" in the table was used simply to indicate the second half of the specimen, there being no welds.

The hot-drawn tubes were made by piercing hot and then hot drawing, no rolling or swedging being done. After leaving the piercing machine one end was closed, and after two draws the other end was closed, and the tube cut in two. The tubes marked *D* in the column, "No. of sample," are those from the ends pointed after the second pass through the dies. Both ends were given three more passes, so those marked *D* were drawn twice in one direction and three times in the other, while those not so marked received all the five passes in the same direction. These tubes were reheated after leaving the piercer and after each draw. All other marks are the same as for the cold-drawn tubes.

Before placing the samples in the tanks, they were weighed to the nearest gramme, their surfaces, including the edges, measured as near as practicable to the nearest one-hundredth of an inch, and the results tabulated.

While in the tanks, the samples were kept covered at all times with distilled water, standing at least an inch over the highest part of the samples. The water in each tank was tested with blue litmus paper at the end of each period of seven days, and at no time showed indications of acidity. At the end of each period of seven days each sample was shifted along to the next position, so that each sample made a complete round of the sixteen positions in the sixteen weeks. Conditions for all twelve tanks were kept as nearly the same as possible, the only difference noted being,

that in shifting the samples the temperature of the water was found to be slightly different, due to the relative positions vertically of the tanks, the greatest temperature being found in those tanks farthest removed from the floor of the room.

At the end of the sixteen weeks period, all the samples were taken out, washed in clean water with a stiff brush, and carefully weighed to the nearest gramme and the results tabulated.

After the tubes were washed in water and weighed, it was found that when dry, the surface became partly covered with a thin film of reddish oxide, which it was concluded would seriously interfere with getting a clear definition of the corrosion in the photographs. Washing the tubes in alcohol to rid them of this objectionable oxide was tried, but with indifferent success. The metallurgist of the Company then suggested that the samples should be dipped in hydrochloric acid to remove the oxide, then immediately dipped in a tub of clear water, and then in ammonia water to thoroughly remove the acid. Upon his assurance that all traces of the acid would be removed by these after baths his recommendation was adopted, the samples being given two washes each in distilled water and in ammonia, the baths in each alternating. They were then dipped in distilled water and dried with a cloth. Finally they were dipped in an alcohol bath and dried with a cloth. This treatment had the desired effect, and the photographs obtained very clearly define the pitting and general corrosion.

In one of the additional tanks, 3 cubic centimeters of strong potassium hydroxide (KOH) was added to the distilled water, and in this tank were placed eight samples of lap-welded steel tubes, not used for the other tanks. The alkalinity of the solution was not determined, nor was any additional KOH added during the test. In all other respects the conditions were the same as in the twelve tanks in which the regular tests were being carried on. As some of the water, lost through evaporation and handling the samples, had to be replaced, there was probably a gradual decrease in the degree of alkalinity of the water in the tank during the trial.

Results.—After tabulating the results obtained from the different samples, a general average of the losses per square inch of

surface area of each class of tube was made. Those averages are as follows:

Class of Tube.	Average loss in grammes.
(1) Hot-drawn seamless steel tubes,	.30667
(2) Lap-welded Bessemer steel tubes,	.31500
(3) Cold-drawn seamless steel tubes,	.32202
(4) Charcoal-iron tubes,	.32596

The difference in the amount of loss in the four classes of tubes is not great, that of the charcoal-iron tubes, which suffered the greatest loss, being, roughly, 6.3 per cent. more than the loss of the hot-drawn seamless tubes, which suffered the least.

Considering the three grades of the hot-drawn seamless tubes alone, it was found that the average losses per square inch of surface area were:

Tubes from top of ingot,	.33124 grammes.
Tubes from middle of ingot,	.30992 "
Tubes from bottom of ingot,	.27887 "

The difference in the losses of these three grades is very marked; those from the top of the ingot losing 18.8 per cent. more, and those from the middle of the ingot, 11.1 per cent. more than those from the bottom of the ingot; the loss from the bottom samples being less, probably on account of the lesser amount of impurities and greater density of the metal of the ingot in this part.

Of the three grades of the lap-welded Bessemer tubes the average losses per square inch were:

Tubes from top of ingot,	.36715 grammes.
Tubes from middle of ingot,	.30004 "
Tubes from bottom of ingot,	.27869 "

The difference here is even more marked for the top of the ingot than in the case of the hot-drawn tubes, those from the top of the ingot losing 31.7 per cent. more, and those from the middle of the ingot losing 7.7 per cent. more, than those from the bottom, the segregation of the impurities and the different den-

sities of the metal at top and bottom of the ingot being again probably the cause of this difference.

When the results obtained from the cold-drawn seamless tubes are investigated, an entirely different result from the first two cases appears. Here instead of the losses increasing from bottom to top of ingot, they increase in the opposite direction.

These losses per square inch of area were:

Tubes from top of ingot, ...	.31300	grammes.
Tubes from middle of ingot, . . .	.32211	"
Tubes from bottom of ingot, . . .	.33095	"

It appears at first glance that these tubes corroded more uniformly than the two former kinds, but an examination of the averages for the separate tanks shows that this is not the case in the individual tanks. While the averages for the individual tanks, both for the lap-welded Bessemer and for the hot-drawn seamless tubes, show the same general results as are shown by the general averages for the three tanks, as to the relative losses of the tubes from the top, middle and the bottom of the ingot, it is not so in the case of the cold-drawn seamless tubes. In only one of the tanks containing specimens of these latter tubes was the loss greatest from the samples taken from the top of the ingot and least in those taken from the bottom. In the second tank the losses were just the reverse, while in the third tank they were greatest in those specimens taken from the top of the ingot and least in those taken from the middle. No reasonable cause can be assigned for this variation from the results that were obtained in the cases of the hot-drawn seamless and the lap-welded Bessemer tubes, unless it may possibly be due to the hot-swedge rolling and cold drawing to which the metal is subjected. This working which the metal receives may have a greater tendency to reduce the metal of the ingot to a more uniform density throughout than the processes for lap-welded and seamless hot-drawn tubes.

In the additional tank, to the water of which the KOH was added, the average loss for the eight samples, all lap-welded Bessemer steel, was only .0997 grammes per square inch. As this tank

Table Showing Loss in Weight of Samples of Steel and Iron

THREE-INCH BOILER TUBES, No. 9 W. G.

No. of sample.	Photo. number.	Total area, square inches.	Chemical analysis. C., per ct.		P., per ct.		S., per ct.		M., p.ct.		Si., per ct.		Ox., per ct.	
			N. T. Co	Gov't.	N. T. Co.	Gov't.	N. T. Co.	Gov't.	N. T. Co.	Gov't.	N. T. Co.	Gov't.	N. T. Co.	Gov't.
T-1-Px	G-2....	54.767	.17	.12	.024	.035	.047	.048	.57	.56	.005	.005	.23	...
T-1-Ox....	G-4....	54 947	.17	.13	.018	.039	.050	.055	.55	.52	.005	.007	.18	...
M-1-Ox....	G-10...	54.519	.15	.12	.017	.032	.042	.043	.53	.59	.005	Tr.	.20	...
M-2-P.....	G-11...	54.441	.17	.13	.015	.038	.045	.046	.54	.59	.005	.003	.30	...
B-1-O.....	G-14...	54.432	.13	.11	.006	.028	.036	.031	.44	.48	.005	Tr.	.33	...
B-2-P.....	G-16...	54 428	.13	.11	.012	.031	.033	.035	.43	.56	.005	.002	.25	...
T-2-Ox....	H-2....	55.201	.18	.13	.022	.038	.049	.051	.52	.52	.005	Tr.	.20	...
M-3-P.....	H-9. ..	55.088	.17	.13	.015	.034	.045	.041	.54	.48	.005	.005	.30	...
B-2-Px....	H-12..	54.996	.13	.11	.012	.031	.033	.035	.43	.56	.005	.002	.25	...
B-2-Ox....	H-14..	54.808	.13	.11	.006	.028	.036	.037	.44	.56	.005	Tr.	.33	...
T-3-Ox....	I-1....	54.484	.18	.14	.022	.039	.049	.057	.52	.62	.005	Tr.	.30	...
T-4-Px....	I-3....	54.752	.17	.12	.024	.032	.057	.049	.55	.58	.005	.004	.25	...
M-3-Ox....	I-6....	53.878	.15	.09	.014	.033	.047	.044	.46	.64	.005	Tr.	.28	...
M-4-O	I-9	54.951	.16	.09	.019	.033	.049	.046	.47	.56	.005	Tr.	.25	...
B-3-Ox	I-12....	53.425	.13	.10	.006	.031	.038	.040	.48	.55	.005	.003	.25	...
B-4-O	I-15....	55.373	.13	.10	.005	.027	.033	.043	.46	.54	.005	.002	.28	...
			THREE-INCH BOILER TUBES, No. 9 W. G.											
T-8.....	J-5....	56.083	.16	.12	.022	.038	.050	.048	.53	.52	.005	.005	.23	...
T-8x.....	J-6....	53.613	.16	.12	.022	.038	.050	.048	.53	.52	.005	.005	.23	...
M-7x.....	J-8....	55.889	.14	.09	.019	.024	.038	.036	.41	.58	.005	.002	.30	...
M-8	J-11....	55.593	.15	.13	.021	.025	.040	.040	.38	.55	.005	.002	.28	...
B-7.....	J-12....	54.718	.13	.11	.006	.024	.030	.031	.53	.53	.006	Tr.	.24	...
B-7-D.....	J-14....	56.490	.12	.11	.012	.025	.031	.032	.48	.53	.005	.003	.38	...
T-11-D....	K-3 ...	54.370	.15	.13	.024	.025	.047	.049	.52	.58	.005	.002	.32	...
T-9-D.....	K-5 ...	55.894	.14	.13	.022	.030	.051	.044	.52	.54	.005	.005	.30	...
M-8x.....	K-6 ...	56.090	.15	.13	.021	.035	.040	.040	.38	.55	.005	.002	.28	...
M-8-D.....	K-7 ..	55.277	.15	.12	.015	.028	.039	.039	.43	.61	.005	Tr.	.37	...
B-8-D.....	K-13 ..	53.725	.13	.10	.012	.021	.033	.027	.51	.60	.005	Tr.	.30	...
B-9.....	K-15 .	55.657	.13	.10	.006	.024	.034	.033	.53	.58	.005	Tr.	.32	...
T-10.....	L-2....	55.847	.15	.14	.026	.032	.043	.047	.54	.55	.005	.005	.27	...
T-10x	L-3....	55.780	.15	.14	.026	.032	.043	.047	.54	.55	.005	.005	.27	...
M-10-D....	L-3....	56.060	.13	.12	.005	.027	.040	.039	.55	.62	.005	Tr.	.33	...
M-10-Dx .	L-10...	54.372	.13	.12	.005	.027	.040	.039	.55	.62	.005	Tr.	.33	...
B-10-D....	L-13...	57.596	.12	.09	.011	.020	.030	.026	.51	.58	.005	Tr.	.29	...
B-11-D....	L-16...	56.662	.12	.09	.011	.021	.032	.025	.49	.60	.005	Tr.	.36	...
			THREE-INCH BOILER TUBES, No. 9 W. G.											
4x	D-4 ...	55.030	Tr.	.02	.032	.040	.011	.004	Tr.	.05	.030	.014	.108	...
14.....	D-15 ..	54 650	Tr.	.02	.034	.035	.012	.010	Tr.	.06	.026	.009	.110	...
18.....	E-3....	54.105	Tr.	.02	.030	.041	.012	.007	Tr.	.03	.021	.025	.120	...
20.....	E-7....	54.604	Tr.	.02	.068	.044	.020	.018	Tr.	.05	.019	.015	.102	...
30x.....	F-6....	54 590	Tr.	.02	.034	.038	.012	.010	Tr.	.02	.027	.030	.128	...
33.....	F-11....	54.841	Tr.	.02	.036	.050	.014	.013	Tr.	.07	.025	.005	.112	...
			THREE-INCH BOILER TUBES, No. 9 W. G.											
1-1x.....	A-2....	54.240	.065	.09	.115	.120	.081	.093	.31	.29	...	Tr.	.35	...
1-3x.....	A-6....	55.081	.065	.09	.112	.118	.077	.084	.29	.29	.006	Tr.	.40	...
7-2x.....	A-10...	54 843	.065	.09	.111	.120	.081	.086	.34	.32	.006	.003	.25	...
7-3.....	A-11...	54.753	.060	.09	.109	.114	.084	.092	.29	.29	.006	Tr.	.25	...
13-1x.....	A-13 ..	53.510	.060	.09	.107	.105	.078	.079	.31	.32	012	.002	.36	...
13-2x.....	A-15...	55 407	.070	.09	.107	.105	.078	.081	.29	.32	.010	.003	.26	...
2-1	B-1....	55.141	.065	.09	.120	.120	.094	.095	.32	.30	.006	.004	.28	...
2-3.....	B-5....	55.182	.070	.09	.114	.122	.089	.090	.31	.30	.006	Tr.	.23	...
8-3.....	B-8....	54.651	.060	.09	.114	.101	.081	.045	.31	.30	.013	.004	.34	...
8-4.....	B-10...	54.882	.070	.09	.109	.112	.078	.084	.28	.30	.006	Tr.	.21	...
13-4x.....	B-14...	52.856	.060	.09	.105	.105	.077	.079	.28	.35	.006	.001	.30	...
14-1x.....	B-16...	54 392	.060	.09	.104	.103	.075	.081	.32	.36	.010	.003	.33	...
3-1.....	C-2....	53.702	.065	.09	.109	.110	.076	.081	.34	.28	.006	Tr	.30	...
3-1x.....	C-3....	54.905	.065	.09	.109	.110	.076	.081	.34	.28	.006	Tr.	.30	...
9-1	C-6....	54.229	.065	.09	.110	.110	.080	.082	.29	.27	.006	Tr.	.21	...
12-1.....	C-9....	53.831	.070	.09	.106	.106	.074	.089	.30	.32	.006	.003	.20	...
14-2x.....	C-12...	53.285	.060	.09	.097	.106	.079	.080	.30	.34	.015	Tr.	.34	...
14-4x.....	C-16...	54.144	.060	.10	.107	.113	.077	077	.31	.32	.009	.002	.21	...

After Sixteen Weeks' Exposure to Air and Distilled Water.

SEAMLESS—COLD DRAWN.

Physical properties.				Original weight, grammes.	Weight after sixteen weeks, in bath, grammes.	Loss in grammes.	Loss per square inch, area, in grammes.	Remarks.
Elastic limit.	Tensile strength.	Elongation, per cent.	Reduction of area, per cent.					
29,080	49,820	22.50	66.7	491	474	17	·3104	Top of ingot.
26,650	49,760	23.13	71.3	509	489	20	.3640	Top of ingot.
39,020	47,920	19.25	70.1	490	474	16	.2935	Middle of ingot.
38,450	55,640	16 63	62 7	489	468	21	.3858	Middle of ingot.
26,830	46,400	24.13	68.6	496	482	14	.2572	Bottom of ingot.
29,350	49,140	23.13	67.9	499	479	20	.3675	Bottom of ingot.
27,290	47,520	18	72.8	505	490	15	.2735	Top of ingot, least.
25,680	48,860	26.88	66.2	507	485	22	.3993	Middle of ingot, greatest.
29,350	49,140	23.13	67.9	498	476	22	.4000	Bottom of ingot, greatest.
28,250	47,950	22.37	72.6	500	480	20	.3649	Bottom of ingot, least.
41,210	58,200	12.25	61.2	475	455	20	.3671	Top of ingot.
40,350	54,040	12.13	63	500	485	15	.2739	Top of ingot.
37,900	60,000	13.13	67.6	467	453	14	.2599	Middle of ingot.
36,830	52,680	13.50	70.2	527	510	17	.3090	Middle of ingot.
28,750	46,180	21.25	70	487	473	14	.2621	Bottom of ingot.
32,010	50,180	19.13	69.6	502	483	19	.3431	Bottom of ingot.

SEAMLESS—HOT DRAWN.

43,100	59,260	21.50	68.1	582	566	16	.3853	Top of ingot.
43,100	59,260	21.50	68.1	515	499	16	.2985	Top of ingot.
41,340	54,560	20	66 5	543	523	20	.3578	Middle of ingot.
35,550	52,400	23.63	68.1	461	452	9	.1618	Middle of ingot.
4,180	53,340	21.50	62	554	539	15	.2742	Bottom of ingot.
36,700	50,780	22.25	70.4	580	568	12	.2124	Bottom of ingot.
34,220	53,620	21.75	68.3	556	548	8	.1419	Top of ingot.
35,960	54,800	26.13	64.3	537	516	21	.3757	Top of ingot.
35,550	52,400	23.63	68.1	553	531	22	.3922	Middle of ingot.
34,920	53,100	23.38	69.7	551	534	17	.3075	Middle of ingot.
36,670	50,060	27.25	71.9	536	523	13	.2420	Bottom of ingot.
37,950	51,240	22.25	64.6	554	535	19	.3413	Bottom of ingot.
37,510	53,840	21.75	68.1	457	440	17	.3043	Top of ingot.
37,510	53,840	21.75	68.1	597	574	23	.4123	Top of ingot.
35,300	53,400	21	70.3	570	551	16	.2854	Middle of ingot.
35,300	53,400	21	70.3	504	484	20	.3679	Middle of ingot.
33,380	49,450	23.13	74.5	524	508	16	.2778	Bottom of Ingot.
31,230	49,130	22.50	70.1	542	524	18	.3177	Bottom of ingot.

LAP-WELD IRON.

26,920	44,750	24	55.7	495	476	19	.3451	.....
24,800	43,500	27.35	56	517	503	14	.2562	.....
27,180	46,480	26.63	65.8	502	478	24	.4436	.....
28,131	49,510	22.63	47.8	505	498	13	.2248	.....
24,450	43,250	25 63	59.8	488	475	13	.2248	.....
27,570	47,510	26.25	58	515	487	28	.5012	.....

LAP-WELD BESSEMER STEEL.

39,450	60,980	20.63	51.1	450	439	21	.3872	Top of ingot.
38,020	58,480	20.38	51.2	489	470	19	.3449	Top of ingot.
37.590	58,960	20.63	58	508	488	20	.3647	Middle of ingot.
37,060	60,980	20.38	50.2	503	488	15	.2739	Middle of ingot.
37,790	59,900	20.50	59.6	511	498	13	.2430	Bottom of ingot.
37,780	58,980	17.38	58.9	513	496	17	.3068	Bottom of ingot.
42,380	61,700	19.38	53.7	514	490	24	.4352	Top of ingot.
40,930	62,420	22.50	51.7	512	494	18	.3262	Top of ingot.
38,460	56,920	22.50	61.1	511	493	18	.3294	Middle of ingot.
37,710	60,500	20.63	62 1	518	504	14	.2551	Middle of ingot.
38,590	58,200	20.25	55.2	519	504	15	.2857	Bottom of ingot.
38,860	59,240	20	51.3	497	479	18	.3310	Bottom of ingot.
36,600	58,080	18.13	58.2	507	487	20	.3785	Top of ingot.
36,600	58,080	18 13	58.2	536	517	19	.3460	Top of ingot.
37,130	58,960	17.63	57.1	496	479	17	.3135	Middle of ingot.
38,740	60,320	22.88	58.4	510	497	13	.2281	Middle of ingot.
36,810	58,460	17	56.1	495	479	16	.3004	Bottom of ingot.
37.750	59,900	18.75	54.7	513	501	12	.2216	Bottom of ingot.

contained samples from the top, middle and bottom of the ingot, and the conditions were, with the exception of the alkali, the same as in the other three tanks containing the lap-welded Bessemer steel tubes, the results obtained from it can be fairly compared with the average of these three tanks. The average loss of these tanks was .31500 grammes per square inch of specimen, so that the loss in the alkiline tank was only 31.6 per cent. of that with the fresh water. This result indicates strongly the wisdom of keeping the water in boilers slightly alkaline at all times as a safeguard against deterioration from oxidation.

While the results obtained would seem to indicate the advisability of using hot-drawn seamless steel tubes, looking at it from the point of loss by corrosion alone, yet in making the choice other points must be considered, as, for instance, not only the amount of corrosion but also the nature of the corrosion, whether spread over a large area or concentrated in pits. Some of the tubes showing a large loss may have this loss spread over a large amount of surface and be only superficial, while others showing a small loss may have this loss concentrated in three or four pits which would destroy the value of the tube much more rapidly than in the other case. From this point of view an inspection of the accompanying photographs would seem to point out the charcoal-iron tubes as being the most desirable.

As has been stated, owing to the limited number of billets from which the cold-drawn seamless tubes were made, it was necessary to take two samples from each tube, one from the open and one from the pointed ends. From an inspection of the full tables it is found that in tanks G and H the corrosion undergone by the samples from the pointed ends exceeded that of the open-end samples by 12.3 per cent. and 15.9 per cent. respectively, while in the remaining tank the open-end sample suffered the most, the corrosion of the pointed-end sample being 3.57 per cent. less. The average excess corrosion of the pointed ends over that of the open ends, however, amounted to 8.5 per cent.

In drawing the hot-drawn seamless tubes, some of the tubes were drawn twice in one direction and three times in the opposite direction, while the remainder of the tubes were passed five times

in one direction only. The averages of these different methods of passing are given in an accompanying table, as are those of the foregoing paragraph. By an inspection of this table it is seen that the average corrosion, in each tank, of the samples from the tubes passed in only one direction exceeds that of those samples which were passed in both directions. These excesses are as follows: Tank J, 8.64 per cent.; tank K, 19.79 per cent.; tank L, 7.78 per cent. The general average of excess is 11.95 per cent.

In the cases of those samples of lap-welded iron and lap-welded Bessemer steel tubes, which include the weld, the appended table shows that the influence of the weld is very slight, the average excess corrosion possibly due to the weld being in the first case only 4.65 per cent., and in the second 3.09 per cent., a difference so slight that it is hardly necessary to take it into account.

Three-inch Boiler Tubes, No. 9 B.W.G., Seamless Cold Drawn.

Average of losses of samples taken from open and pointed ends.

	Loss in grammes per sq. in.
Tank G, open ends,	.3109
H, " "	.3108
I, " "	.3000
Average, all open ends,	.3072
Tank G, pointed ends,	.3502
H, " "	.3603
I, " "	.2893
Average, all pointed ends,	.3333

Three-inch Boiler Tubes, No. 9 B.W.G., Seamless Hot Drawn.

Average of losses from tubes passed in one direction and in opposite directions through dies.

	Loss in grammes per sq. in.
Tank J, five passes in one direction,	.2967
K, " " "	.3367
L, " " "	.3421
Average, five passes in one direction,	.3252

Tank J, two passes in one, three in opposite direction,	.2731
K, " " " " "	.2809
L, " " " " "	.3174
Average, ...	.2905

Three-inch Boiler Tubes, No. 9, B.W.G., Lap-weld Iron.

Average losses of samples with and without welds.

	Loss in grammes per sq. in.
Tank D, with welds, ...	.3400
E, " "	.3704
F, " "	.2962
Average, ...	.3355
Tank D, without welds, ...	.3066
E, " "	.3469
F, " "	.3083
Average, ...	.3206

Lap-weld Bessemer Steel.

Tank A, with welds, ...	.3371
B, " "	.3328
C, " "	.2925
Average, ...	.3208
Tank A, without welds, ...	.3124
B, " "	.3242
C, " "	.2941
Average, ...	.3102

SEAMLESS HOT DRAWN.—RECAPITULATION.

Average Loss in Grammes per Square Inch.

Average of—	Tank J.	Tank K.	Tank L.	Tanks J, K and L.
Tank, . .	.28420	.30710	.32872	.30667
Top, . .	.34241	.30800	.34330	.33124
Middle, .	.27098	.33645	.32232	.30992
Bottom, .	.23922	.27684	.32055	.27887

Averages of Chemical Analyses.

NATIONAL TUBE CO.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
Tops, . .	.15	.022	.046	.52	.005	.28
Middles, .	.14	.015	.039	.44	.005	.30
Bottoms, .	.13	.010	.031	.51	.005	.32
All tubes, .	.14	.016	.039	.49	.005	.30

GOVERNMENT.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
Tops, . .	.13	.029	.045	.54	.004	—
Middles, .	.12	.017	.037	.57	.002	—
Bottoms, .	.10	.023	.028	.53	.002	—
All tubes, .	.12	.023	.037	.55	.003	—

LAP-WELD BESSEMER STEEL.—RECAPITULATION.

Average Loss in Grammes per Square Inch.

Average of—	Tank A.	Tank B.	Tank C.	Tanks A, B and C.
Tank, . .	.32036	.329047	.29559	.31500
Top, . .	.36618	.38636	.34890	.36715
Middle, .	.31580	.30614	.27818	.30004
Bottom, .	.27908	.29714	.25987	.27869

Average of Chemical Analyses.

NATIONAL TUBE CO.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
Tops, . .	.065	.114	.088	.30	.006	.30
Middles, .	.064	.109	.079	.31	.007	.32
Bottoms, .	.061	.106	.077	.31	.009	.32
All tubes, .	.063	.110	.081	.31	.008	.28

GOVERNMENT.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
Tops, . .	.09	.117	.089	.29	.004	—
Middles, .	.09	.110	.080	.30	.003	—
Bottoms, .	.09	.105	.080	.33	.002	—
All tubes, .	.09	.111	.083	.31	.003	—

SEAMLESS COLD DRAWN.—RECAPITULATION.

Average Loss per Square Inch.

Average of—	Tank G.	Tank H.	Tank I.	Tanks G, H and I.
Tank, . .	.33474	.33529	.29602	.32202
Top, . .	.34605	.28900	.30394	.31300
Middle, .	.34330	.33370	.28934	.32211
Bottom, .	.31488	.38318	.29479	.33095

Averages of Chemical Analyses.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
Tops, . .	.18	.023	.050	.54	.005	.23
Middles, .	.16	.013	.043	.51	.005	.22
Bottoms, .	.13	.010	.036	.46	.005	.24
All tubes, .	.16	.015	.043	.50	.005	.23

GOVERNMENT.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
Tops, . .	.13	.036	.048	.57	.003	—
Middles, .	.11	.033	.043	.57	.003	—
Bottoms, .	.10	.029	.035	.56	.003	—
All tubes, .	.11	.033	.042	.57	.003	—

LAP-WELD IRON.—RECAPITULATION.

Average Loss per Square Inch in Grammes.

Average of—	Tank D.	Tank E.	Tank F.	Tanks D, E and F.
All tubes,	.31702	.35862	.31224	.32596

Average of Chemical Analyses.

NATIONAL TUBE CO.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
All tubes, .	Trace.	.038	.014	Trace.	.024	1.03

GOVERNMENT.

Average of—	Car.	Phos.	Sul.	Man.	Si.	Ox.
All tubes, .	.02	.043	.011	.044	.012	—

Plate I.—Hot-Drawn Seamless Steel Tubes, Showing Least Amount of Corrosion.

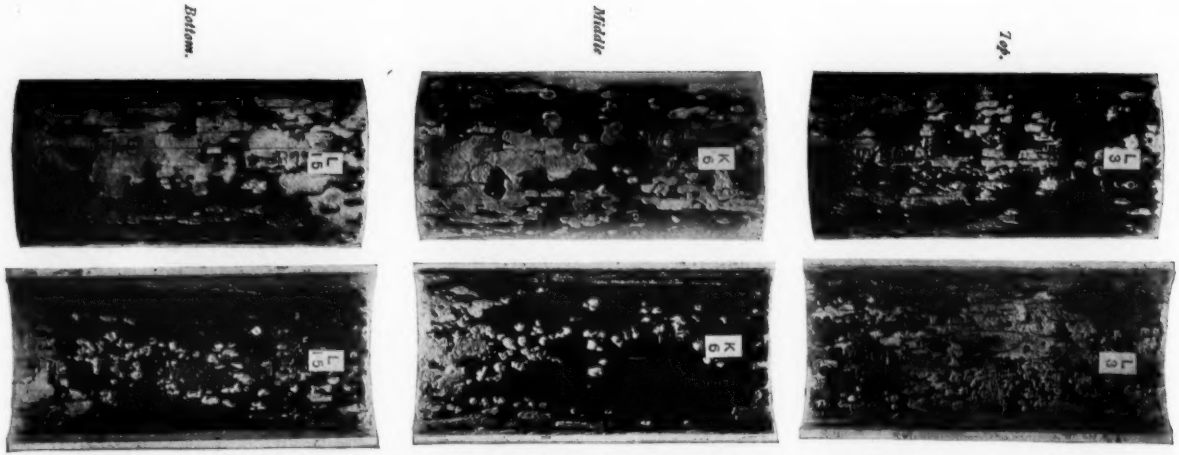


Plate II.—Hot-Drawn Seamless Steel Tubes, Showing Greatest Amount of Corrosion.

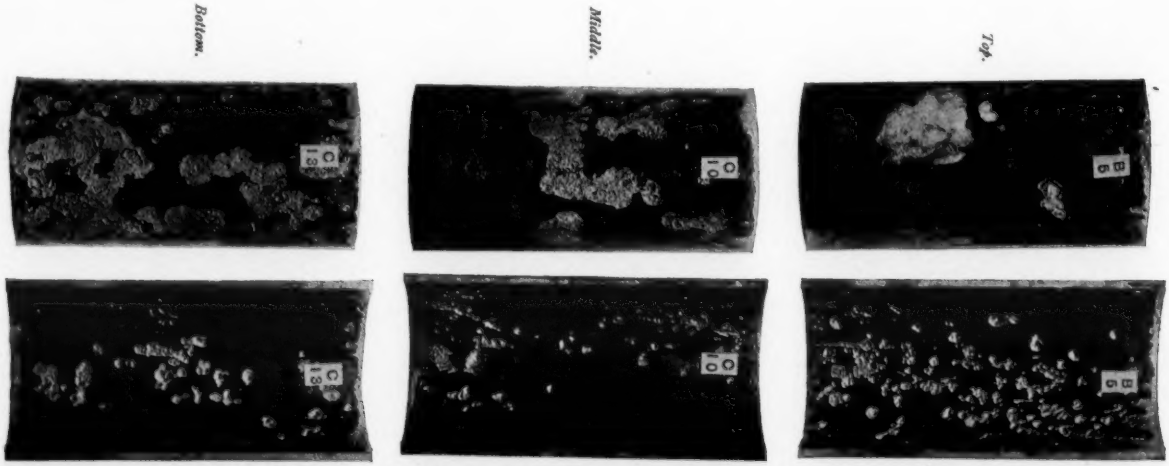


Plate III.—Lap-Welded Bessemer Steel Tubes, Showing Least Amount of Corrosion.

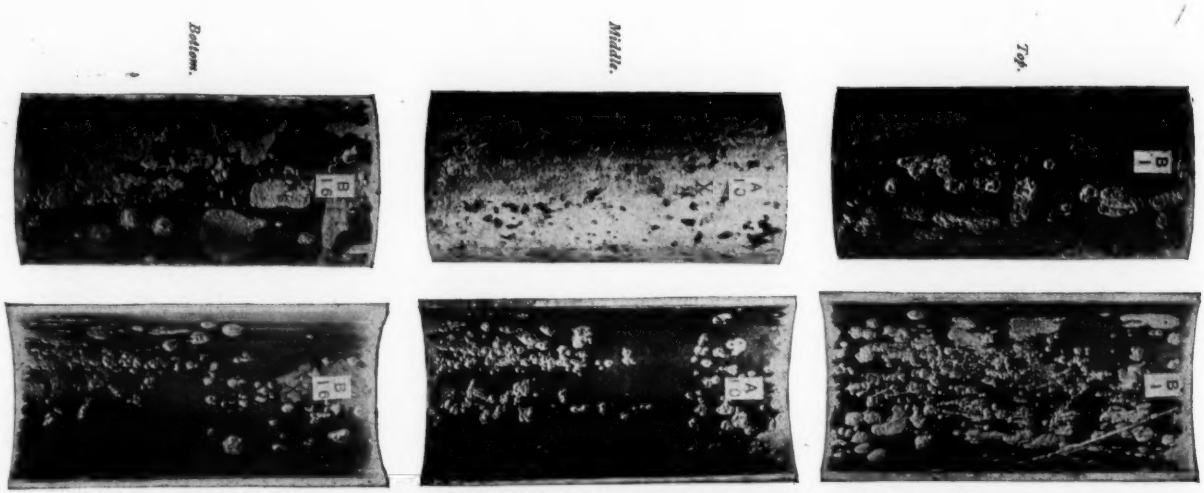


Plate IV.—Lap-Welded Bessemer Steel Tubes, Showing Greatest Amount of Corrosion.

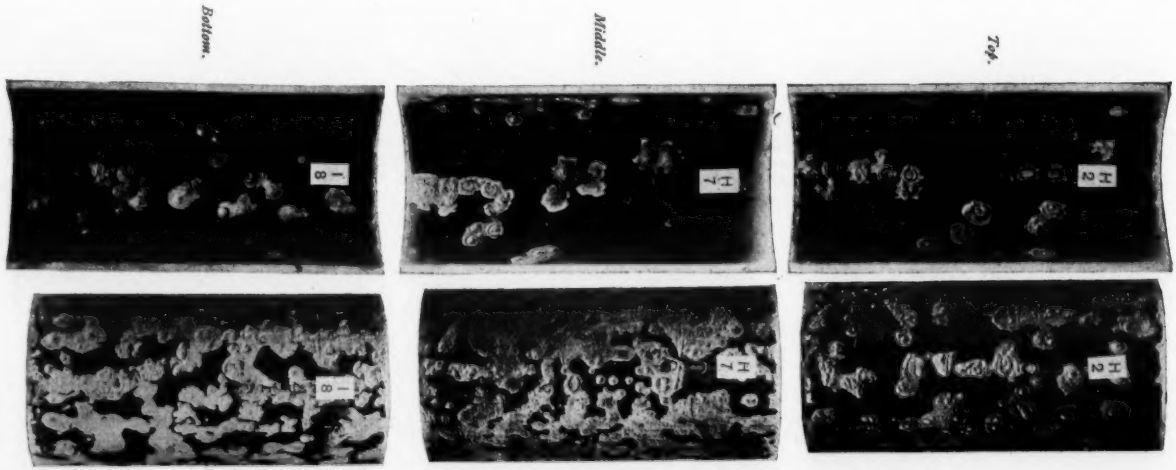


Plate V.—Cold-Drawn Seamless Steel Tubes, Showing Least Amount of Corrosion.

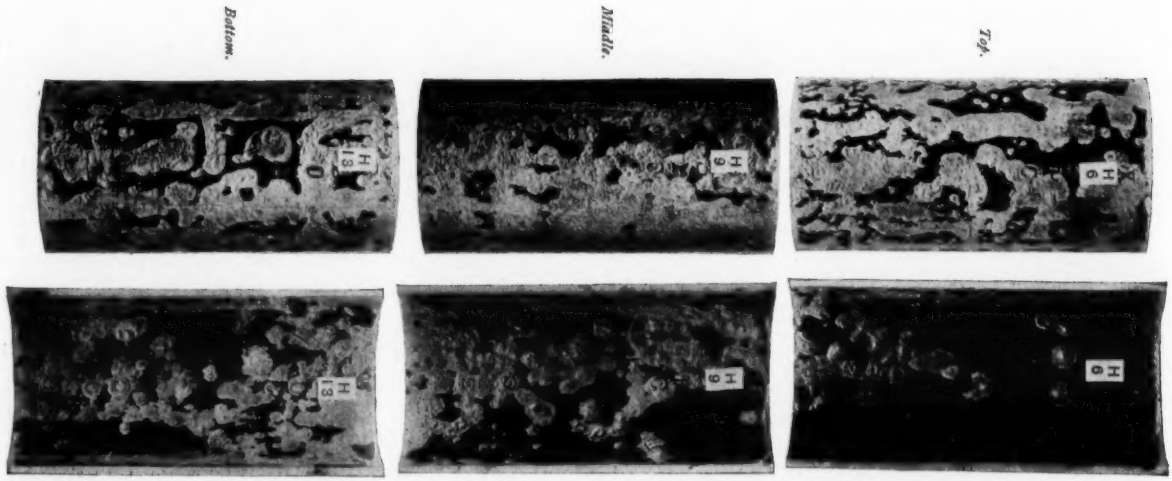


Plate VI.—Cold-Drawn Seamless Steel Tubes, Showing Greatest Amount of Corrosion.

Least. *Greatest.*

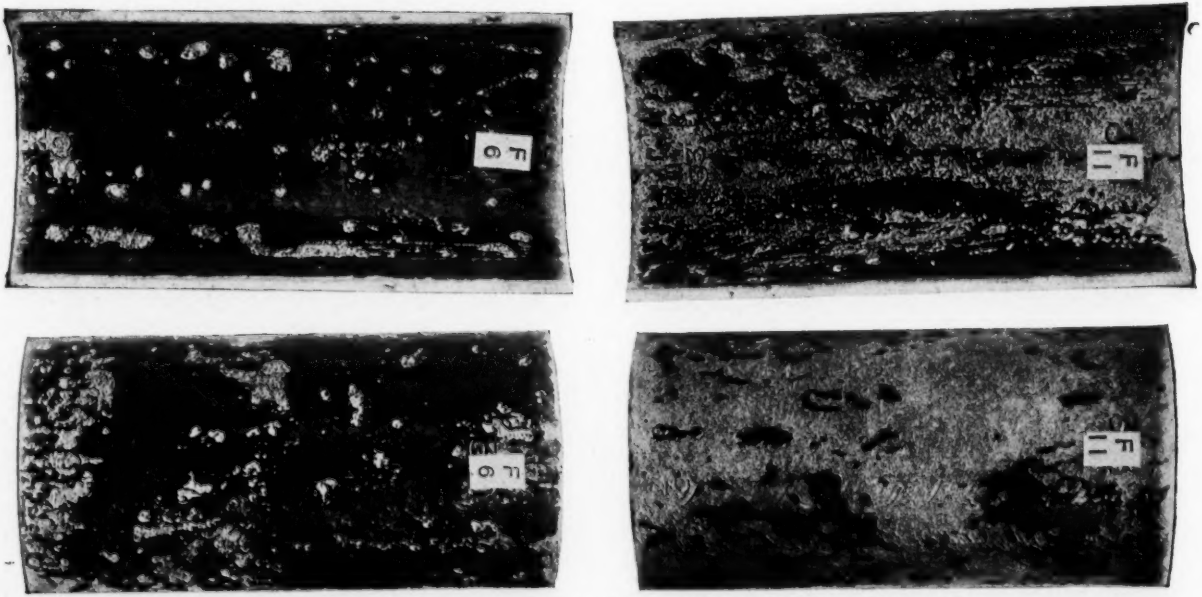


Plate VII.—Charcoal-Iron Tubes, Showing Least and Greatest Amounts of Corrosion.

Least amount.

Greatest Amount.

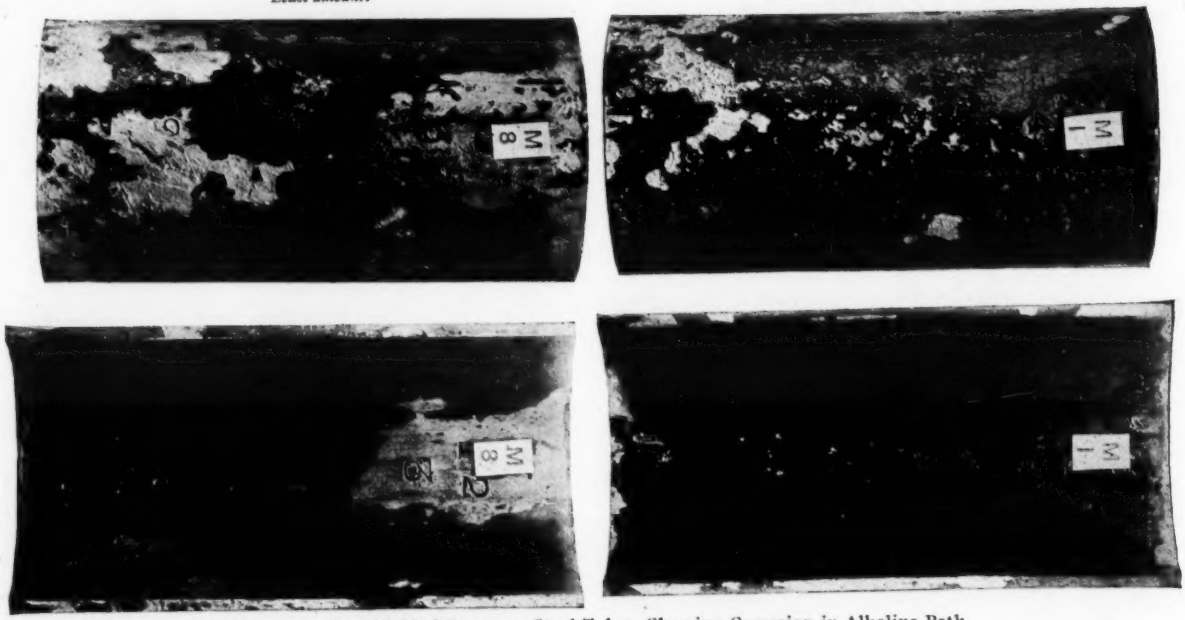


Plate VIII.—Lap-Welded Bessemer Steel Tubes, Showing Corrosion in Alkaline Bath.

LAP-WELD BESSEMER STEEL TUBES.—ALKALI BATH.

Sample No.	Photo. No.	Kind of material.	Total area in sq. in.	Original w't, grammes.	Weight after 16 weeks.	Loss in grammes.	Loss per sq. in., grammes.
3-4	M-1	Lap-weld Bessemer steel.	54.192	495	492	3	.0553
4-1	M-2	Ditto.	54.655	514	507	7	.1283
4-1-x	M-3	Ditto.	53.859	512	509	3	.0557
4-2	M-4	Ditto.	55.464	518	515	3	.05409
7-3	M-5	Ditto.	54.226	507	563	4	.0737
12-2	M-6	Ditto.	54.703	515	509	6	.1096
12-3	M-7	Ditto.	54.785	503	497	6	.10945
12-3-x	M-8	Ditto.	55.907	537	519	18	.2112

Three cubic centimeters of strong potassium hydroxide (KHO) added when test was started.

Total average of tank, .0997.

CARBONIC ANHYDRIDE ICE MACHINES OF CAPTURED SPANISH GUNBOATS.

By Lieutenant Urban T. Holmes, U. S. Navy.

As readers of the JOURNAL are not generally familiar with this machine or its performance, the following notes may be of interest:

These machines, made in England, by J. & E. Hall, were supplied to the *Isla de Cuba*, *Isla de Luzon* and *Don Juan de Austria* when these vessels were refitted at Hongkong in 1899.

Each machine has a vertical single cylinder, with inverted compressor cylinder connected directly to the crosshead. There is a fly wheel with overhung crank, and the two pumps, brine pump and circulating pump, are arranged in tandem and driven from a crank at one end of shaft. All these parts are bolted to the condenser shell, which is a cylindrical casting and stands upright.

The compressor is double acting, and works at a pressure of 100 atmospheres. To ensure its proper lubrication and keep the packing tight there is an oil cylinder, arranged with a piston and a spring back of it, both sides being in communication with the compressed gas. A hand pump serves to pump oil into this cylinder, and the spring then forces it into the compressor-rod

stuffing box. A separator removes the oil from the gas before it enters the condenser.

The condenser is a single copper coil, contained in an annular space inside the shell. The inner wall of condenser chamber is the outer wall of expander chamber, and the expander is a second single copper coil, contained in this chamber. A strong brine of chloride of calcium is circulated through the expander chamber and the coils of refrigerator chamber, freezing box and scuttle butt by means of the brine pump.

The gas goes to compressor cylinder after it has passed through the expander. It is compressed, and after it has passed through the oil separator it passes through the condenser, where it is liquefied. It then goes to the "regulator" valve, where it is allowed to flow, in gaseous form, into the expander.

To charge the machine initially, and make up losses, there is a connection to a tank of liquid carbonic-acid gas, immediately adjoining the regulator valve. These tanks contain about 35 pounds of gas each, and one tank will ordinarily last a month, after the machine is charged. To charge the machine about half a tank is required.

On the U. S. S. *Isla De Luzon* this machine worked very satisfactorily, preserving 3,000 pounds of meat, cooling the scuttle butt, and making ice enough for the officers' use. When turned on the freezing box, it has frozen two cakes of ice from warm water in one and a half hours from the time of starting up. Its efficiency was greatly increased by fitting a copper drum inside the expander coil to force the cooling brine to circulate properly about the coil. It was found that there was much greater economy of gas by disconnecting the tank after each charge and sealing the discharge nozzle, owing to minute leaks in the long tube connection. Difficulty was experienced in getting chloride of calcium, so common salt was used and appeared to answer the purpose just as well, provided that the brine was made somewhat stronger.

Owing to the high pressure under which the compressor works, it is absolutely necessary that the oil supply must be constant. Any stoppage of oil will cause the piston to heat, the packing

leathers will burn out, and injury to the cylinder will inevitably result. For this reason a very careful man must be constantly in attendance on the machine.

Comparing this machine with the air machine in use generally in the service, the carbonic-acid machine is more efficient, and, if carefully handled, is easier to keep in order. It is necessary to carry a supply of liquid carbonic-acid gas, besides salt for the brine, which makes the total weight and space required somewhat greater.

DESCRIPTION OF WALKING-BEAM COUNTERBALANCE AS USED IN THE STEAM ENGINEERING SHOPS OF THE MARE ISLAND NAVY YARD, FOR TURNING LAUNCH CRANK PINS.

Note by Commander A. F. Dixon, U. S. Navy.

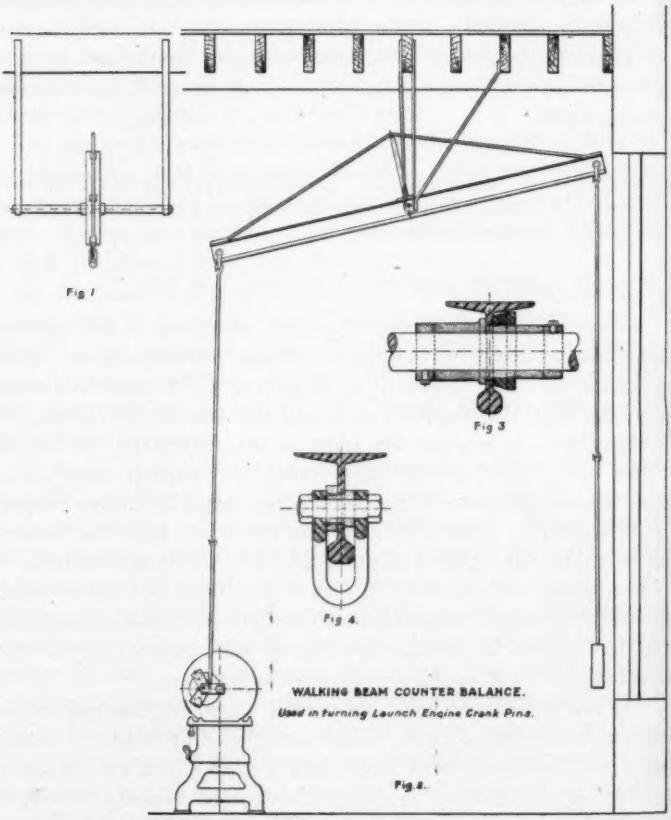
In turning the crank pins of a crank shaft, one of the several difficulties is that of providing a suitable counterbalance. The necessity for and difficulty in arranging such counterbalance increases with the length of shaft and the number of cranks.

Many launch engines are built at this yard, and the crank shafts, being light, can be more easily and cheaply done in a lathe whose faceplate is not sufficiently large to carry a proper counterbalance; particularly is this the case with the three-throw shaft of the type Z engines designed for 50-foot cutters.

In order to do this work properly in a lathe of suitable size, the walking-beam counterbalance herein described was designed, and has proved so satisfactory that a more general use of the idea (which is not entirely new) is recommended.

The machine made and used in the steam engineering shops consists of a walking beam 10 feet 10 inches long, made by trussing a piece of 6-inch deck beam with a strap $\frac{3}{8}$ inch by 2 inches, having in its center a properly constructed bearing through which is passed a 2-inch shaft of sufficient length to admit of any required movement of the beam parallel with the lathe. The shaft rests in strap hangers secured to the timbers above, each hanger having a brace secured to timbers above, and bolted at the lower end by a bolt that passes through the hanger, shaft

and brace. This makes a simple but efficient support for the beam. At each end of the beam is a bearing for the attachment of a clevis from which detachable hook rods are hung. A weight, sufficient to balance the shaft to be turned, is secured to one of



these rods, the rod being of such length as to suspend the weight but slightly above the floor.

The shaft is rough turned and the crank webs removed before work upon the crank pins is begun.

The beam having been adjusted upon its shaft, the required weight attached, the broad hook is passed under a turned portion of the shaft and the lathe is ready.

On the type Z crank shafts a counterweight exceeding 300 pounds was required, which makes apparent the necessity for a good bearing for the walking beam.

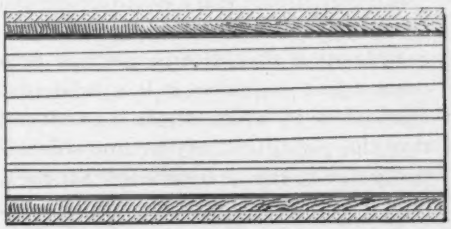
Referring to the accompanying sketches, Figs. 1 and 2 are elevations showing the beam and beam shaft as attached to the timbers of the second floor. Fig. 3 is a detail of the center bearing, and Fig. 4 a detail of the clevis bearings.

To Mr. W. G. Luper, first-class tool maker, is due the credit for this device.

RENEWING LIGNUMVITAE LININGS.

AMERICAN SOCIETY OF NAVAL ENGINEERS: Apropos of Lieut. Leopold's description of method employed in renewal of lignumvitae linings to stern bearings of U. S. S. *Oregon* as published in last number of the JOURNAL, it might be of interest to note the method and the result of the Hong Kong and Wampoa Dock Co. in the case of the U. S. S. *Newark* last spring.

The sleeves, of composition, were in one piece, *i. e.*, not in halves. The lignumvitae strips were separated by metal projections, thus:



and were fitted by hand tools to the sleeves, each section of strip being in two pieces, wedged together so as to secure them permanently in the sleeves, after which they were bored in a boring mill or lathe.

The workmen were Chinese, and the fitting was accurately and rapidly done; but on attempting to replace the sleeves in the stern tubes, the former were found too large. Evidently the sleeves had been stretched by the wedging action of the lignum-vitae strips, the edges of which, being so hard and smooth, had transmitted lateral strains on the sleeves which aggregated in proportion to the number of the strips. It was found necessary to reduce the outside diameter of the sleeves by turning in lathe, and some time was lost thereby, and that valuable to the dry-dock people. The thickness of the sleeves, as I remember them, was about one-half inch, and the stretching of the metal had not been anticipated. As object lessons are instructive, I present this to the readers of the JOURNAL by way of precaution, lest their fates lead them into the same experience unwarned. As some lateral stress must be placed on the sleeves in the employment of wedge form of lining, suitable precaution should be provided against stretching the metal, as by accurately-fitted reinforcing clamps made in halves, or by careful calipering during the progress of the work of applying the lining strips.

W. M. LITTLE, *Lieut. Commander, U. S. N.*

NAVY YARD, NEW YORK, *April 7, 1902.*

CONDENSERS IN WARSHIPS.

It is well known that the surface condensers in the Royal Navy give a great deal of trouble. Their failures do not receive the consideration they deserve, perhaps because public attention is concentrated on boilers. It is held that the breakdown of the mechanism by which steam is produced is much more serious than the giving out of that by which it is destroyed. This is partly due to the circumstance that the cracking of a condenser tube does not endanger life, while the splitting of a boiler tube may mean a dreadful catastrophe. The repair of a condenser, again, is much more easily effected, and in less time, and at less cost, than the mending of a boiler. But, for all this, the repeated breaking down of condensers is a very serious matter. We have often directed attention to this subject, and we have endeavored

to obtain information about it, with results which are to some extent startling, and calculated to modify opinions long held to be founded on facts. We have not succeeded, we may say at once, in obtaining any definite information concerning what goes on in our own Navy. There may be reasons for reticence. Concerning condensers in the United States Navy, however, the case is different, and what we have learned may, we have every reason to believe, very well represent what takes place in our own ships of war.

Copper may be said to have enjoyed the reputation of being akin to precious metals. It does not corrode like iron or steel. It is fairly flexible, ductile, and in various ways an excellent engineering material. Not until within comparatively recent years have doubts been thrown on it. These were created by certain steam-pipe fractures which occurred soon after high pressures were adopted at sea. While pressures did not exceed 40 pounds or so there was no trouble; as soon as they got to 160 pounds steam pipes began to lose their reputation. Various inquiries were carried out. It was early learned that it was not the high pressure alone that was in fault. The diameters of the pipes admitted of being reduced as the pressure augmented. The principal fact which came into prominence was that copper is much reduced in strength by being heated. But this was not all. There is good reason to believe that copper is a highly unstable metal. It is known that all metals are liable to molecular change, and that they depend for their resisting power very largely, and in some cases not at all well understood, on their temperature. Thus, for example, a small rod of tough, soft steel, which may be tied at the ordinary temperature of a room into a knot, will, if chilled in liquid air, fly into a dozen pieces if struck with a fitter's hammer. Copper, if heated and cooled repeatedly, appears to undergo a distinct molecular change. Now, hitherto, it has been supposed that this change only took place at high temperatures. It has been known, indeed, for some time that the copper winding used in electro-magnets and dynamos undergoes deterioration. This has been attributed to the action of the electric current, which operates in a way not understood, and the

facts have not been regarded as of any significance for engineers. The range of temperature in wire of the kind being too small, it is asserted, to be influential, the change is attributed to electricity alone. It will be seen, however, from what follows, that this may be a mistaken view, and that even at quite low temperatures a ruinous molecular change may take place in copper, and in certain of the alloys of which it forms the main constituent.

In the United States Navy much trouble has been experienced from the failure of the Muntz metal condenser tubes, and it is held at the Washington Navy Yard that the trouble is mainly due to making the condensers too small for their work. The most noteworthy defect of several, which we shall notice further on, is that the tubes disintegrate and lose strength a short time after they have been put to work. Whether this is or is not due to the breaking up of the alloy we cannot say. They become so brittle that they may be broken up into small fragments with the greatest ease. It is held that this result is due to the tubes being called upon to transmit too much heat—that, in short, the passage of successive waves of heat as the exhaust ports open and close works a molecular change. Formerly twice or two-and-a-half times as much cooling surface was allowed for a given power as is now available, and there was no trouble. There is practically no trouble now with condensers in the mercantile marine. How or why the transmission of heat should operate to this end is not stated. There is, however, another cause of disintegration at work; the tubes used are very long, and the diameter small. Tubes $\frac{5}{8}$ inch in diameter and only 18 or 20 gauge thick are quite common. When the steam rushes into the condenser in rythmical beats, it apparently sets the tubes vibrating, and this may go far to explain the brittleness which undoubtedly is manifested by the tubes, and that to a very remarkable extent after they have been some time in use. Furthermore, it is the fixed opinion of competent authorities at the other side of the Atlantic that simply drawing a 16-gauge tube two gauges thinner, or down to 18 gauge, notwithstanding the annealing, "takes the life out of the metal"—that, in fact, the thin tube cannot be equal in quality to the tube which is thicker.

These facts and opinions deserve careful consideration from metallurgists at this side of the Atlantic.

Turning, now, to the other causes of failure, to which we have referred above, we find that when corrosion takes place it always occurs on the sea-water side of the tube; the steam side remains unaffected. The tubes most likely to fail are those near the top of the condenser, which receive the first blow of the exhausting steam. These tubes fail either because of the destructive molecular change which we have named, or from pitting, or because they split. Again, the tubes are all packed with tape and screwed glands, and with thin tubes, Nos. 18 or 20, it is very difficult to keep the ends tight. The tubes, it seems, will not stand up to the pressure of the packing in the tube plates, and leak.

It must be understood that what we have here stated represents facts, and the deductions of trained engineers from those facts. The remedy is simply to use much larger condensers, with more tube surface, and more widely-spaced tubes, the metal of the tubes to be thicker—in a word, condensers more like those in the mercantile marine. The rage for keeping down the size and weight of machinery in fighting ships seems likely to be followed by a reaction in favor of a more generous treatment. It is, at all events, certain that the present policy of cutting down everything seriously imperils the efficiency of warships. A few tons more in the engine room would make no perceptible difference in displacement; but it would make all the difference in the world in the efficiency of the ship as a fighting unit.—London "Engineer."

THE FRENCH NAVY.

In a discussion of the French Naval estimates, Admiral de Cuverville, turning to the submarines and submersible boats, points out that they fulfil entirely different conditions, the submarine, propelled exclusively by electrical power, being suitable only for coast defense, while the submersibles, with an oil engine for traveling at the surface and an electrical motor for moving under water, possess a much wider range of action. The Government has been reproached with not putting a larger number

of submarines on the stocks, but Admiral de Cuverville fully approves of the official reserve, since he argues that while the electric submarine has proved itself very efficient for coast defense, the storage batteries offer a good many inconveniences, and in the present development of electrical science it is wise to proceed cautiously. Nevertheless, the Admiral is of the opinion that the submarine is a very useful auxiliary, as was proved during the maneuvers at Ajaccio last year. With the quick-firing guns now employed it is impossible for a torpedo boat to get within striking distance of a battleship or cruiser in the daytime, but the submarine is able to approach without being observed, though we may recall that at Ajaccio the submarine itself was, theoretically, blown out of the water when it had launched the torpedo. The Admiral recommends that a couple of submarines be sent to Diego-Suarez to complete the defense of that "Key to Madagascar," for during the events of 1898, when England and France were on the point of coming to blows, the French Government was well aware that a British fleet was standing off Diego-Suarez ready for attack, and if the port—at that time practically undefended—fell into the hands of the British they would have had entire command of Madagascar.

Summing up his criticisms, Admiral de Cuverville urges that it is necessary to make a new classification of the fleet, and separate the vessels which entirely fulfil the conditions of attack and defense from those that do not possess the same fighting value, these latter being relegated to the second line. If this were done, France would find her first line considerably diminished. The Superior Council of the Marine has estimated that the country needs twenty-four first-line-of-battle ships, but our neighbors are far from possessing this number. The Admiral has a poor opinion of the swift cruisers as constructed in France. He says that they are only suitable for fleeing before the enemy, and he argues that France does not require this type of vessel. Her genius is one of attack, and not of defense.

The Minister of the Marine, whose sympathies are entirely with the advocates of a homogeneous and powerful fleet, claims that he has been closely following the lines laid down by Admiral

de Cuverville, as is proved by the fact that all the six battleships being constructed under the existing program are of identically the same type. At the time he became Minister there were six submarines or submersibles either afloat or on the stocks, and since then thirty-one have been put under construction, while during 1902 thirteen others are to be started upon.—The London "Engineer."

EXPERIMENTS WITH CONDENSER TUBES AND BOILER TUBES BY YARROW AND CO.

The objects of these experiments were:—(1) To try the effect of tinning and nickel plating on brass condenser tubes. (2) To try the action of fresh and salt water on condenser tubes under various conditions of temperature, pressure, or gas in solution. The specimens were all of the same size, and were experimented upon at the same time. All the specimens were weighed every ten days, with the exception of the sealed specimens, which were weighed after 275 days. In the case of the sealed specimens the hydrogen or air was only present in a small quantity between the stopper and the surface of the water; the object aimed at was to seal the specimens in the boiling water with as little air as possible. In one of the nickel-plated specimens the nickel plating at one end was defective, and this tube pitted badly at this end. With the exception of this nickel-plated specimen the corrosion was more or less uniform over the surface, and in some cases it made the tube look striated longitudinally.

The loss, in milligrams, per square inch for ten days, is as follows:

Ordinary brass condenser tube:

Sealed with boiled sea water and hydrogen,	.06
Sealed with boiled sea water and air,	.14
Sea water open to air,	1.54
Sea water with air bubbling through,	1.82
Sea water at 100 degrees Fahrenheit, and open to air,	1.54
Sea water at 10 pounds pressure,*	1.27
Plain water at 10 pounds pressure,*	.20
Distilled water at 10 pounds pressure,*	.16

* This pressure was not constant.

Tinned brass condenser tube:

Sealed with boiled sea water and air,	.11
Sea water open to air,	.54
Sea water with air bubbling through,	.66
Sea water at 100 degress Fahrenheit, and open to air,	.88

Nickel-plated brass condenser tube:

Sealed with boiled sea water and hydrogen,	.04
Sea water open to air,†	.45
Sea water with air bubbling through,	.36
Sea water at 100 degrees Fahrenheit, and open to air,	.55

All pieces from the same mild-steel tube:

Sealed with boiled sea water and hydrogen,	.11
Sealed with boiled sea water and air,	.30
Sea water open to air,	4.40
Sea water with air bubbling through,	7.85
Sea water at 100 degrees Fahrenheit, open to air,	8.20
Sealed with boiled town water and hydrogen,	.19
Town water open to air,	3.46
Sealed with boiled distilled water and hydrogen	0.14
Sea water at 10 pounds pressure,*	2.13
Town water at 10 pounds pressure,*	1.47
Distilled water at 10 pounds pressure,*	2.14

The general conditions of these tests were the same as for condenser tubes.—London "Engineer."

A FRENCH VIEW OF WATER-TUBE BOILERS.

In a comparison between the Belleville, d'Allest, and Niclausse types, based on the results of trials made on board ship with these three types, and taking the coal consumption per horsepower hour with the Belleville boiler as unit, the following figures are given by M. Bertin of the French Navy:

	Belleville Boiler.	d'Allest Boiler.	Niclausse Boiler.
Speed trial,	1	.858	.905
Consumption trial,	1	1.083	1.089

* This pressure was not constant.

† This one had pits due to defective nickel plating.

which show that the advantage would lie with the Belleville boiler when the fires are not forced. M. Bertin states that the every-day experience goes to prove that the Belleville and the Niclausse types, when new and in good condition, are satisfactory as regards simple construction, resisting power under variations in temperature, and the facility with which they can be taken to pieces for inspection. In this last respect the Niclausse boiler would be superior to all others, but would require particular care for keeping it in good order. The DuTemple and Normand boilers—styled boilers with accelerated circulation—have never been tried in competition with the three types above referred to; they have mostly taken the place of locomotive boilers on board the smaller ships, and have shown marked advantage as regards good working and good utilization of the heat, at all events for high rates of combustion. The author says actual working has proved that a rate of combustion of 400 pounds per square meter can be demanded of them with a higher degree of safety than a rate of 300 pounds in boilers with limited circulation (with coiled tubes, such as the Belleville boiler), or in boilers with free circulation (such as the Joessel, d'Allest, Collet, Niclausse, and Babcock and Wilcox types).

But the DuTemple and Normand boilers are inferior to the Belleville, Niclausse, and d'Allest types, and especially inferior to the Niclausse with regard to facilities for cleaning, inspection, taking to pieces and repairs. Their use on large ships would, therefore, be surrounded both with advantages and disadvantages. The DuTemple boilers have, however, a quality which may more than compensate for the difficulty of cleaning. All the types with horizontal tubes (those with free circulation) are without combustion chambers; the hot gases reach the tubes before they are burned, giving an abundance of smoke, and causing the rapid formation of soot deposits. This, according to M. Bertin, is the motive which led Joessel to abandon the type in question. Progress has been made in this line, it is true, but defects still remain. The Belleville economizers, for example, have reduced the amount of smoke, but have no action on the choking up of the main coils of tubes; and the cleaning of these

boilers, though it be comparatively easy to carry out, is a necessary operation at frequently recurring intervals. On the other hand, the boilers with tubes almost vertical, forming a kind of vault above the grate, have a large combustion chamber, resulting in an excellent combustion when the direction of the flames is judiciously regulated. Mr. Weir has been able to do away completely with the smoke and soot, rendering cleaning out in service unnecessary. M. Bertin is of opinion that in the British Navy the Belleville boilers ought to have been used at first in conjunction with cylindrical boilers on the same ships, so as to allow the men to get gradually initiated in their working.

The cost of the Belleville boilers purchased by the French Navy, in the last few years during which this type had to compete with the cylindrical boilers, works out at £27 10s. to £35 12s. per square foot of grate area, with an average of £32. The Niclausse boilers of the *Friant* cost £32. The cost of the d'Allest boilers was slightly higher; it varied between £27 10s. and £38 10s., with an average of £33 8s. The question of first cost could not, therefore, influence the choice of one type rather than any of the others. The cost of cylindrical boilers at the same period was £29 15s. for return-tube, single or double-ended boilers; £48 8s. for through-tube boilers, of the French Admiralty pattern, and £52 15s. for boilers on the locomotive type. The comparison under this head is favorable to the water-tube boilers.

In taking the work per square foot of grate area, the water-tube boilers become dearer, by one-quarter, than the return-tube boilers; but they remain cheaper, by one-tenth, than the Admiralty type, which type had almost entirely superseded, of late years, the return-tube boilers. The prices of water-tube boilers paid by the French Admiralty since the abandonment of the cylindrical type are of special interest. These prices vary to a large extent: Thus, the Belleville boilers of the *Sully* cost £44 15s. per square foot of grate area, and £53 10s. for the *Victor Hugo;* the Niclausse boilers for the *Gloire* and *Condé* cost £45 12s., and for the *Léon Gambetta* £54. The DuTemple boilers of the *Dunois* and *Lahire* cost £64 15s., and the large ones for the

Montcalm £66 16s. per square foot of grate area. All these figures are for the boilers fitted with their accessories, the cost of which enters in the prices for about 37 per cent. The economical side of the question depends upon the duration of the boilers, and a decision on this point must be left for a later date as regards the water-tube types.—London "Engineering."

SUPERHEATED STEAM.

Some Experiences and Results Derived From the Use of Highly Superheated Steam in Engines.

By Mr. R. Lenke, of Erith. Paper read before the International Engineering Congress, Glasgow, 1901. Section III: Mechanical.

In no branch of heat-engine building has such an amount of study been spent as in steam engines, from Watt's time up to to-day. The economy of the steam engine is, in spite of all efforts, not the best, and the steam engine, in its highest perfection attainable at present, cannot claim the first place in comparison with other heat engines. And so the problem of generating and using superheated steam has become a question, from the solution of which a considerable stride in improving economy has been expected and really made.

Superheated steam is generated by the addition of heat to saturated steam. The behavior of superheated steam is similar to that of gases; it is a very bad conductor of heat, and has the special peculiarity of being able to lose a certain amount of heat without becoming saturated or wet steam. The thermal capacity of steam is only 0.48, therefore very little heat is required to superheat steam; but as the steam loses the heat as quickly as it acquires it, every passage conveying superheated steam must be well covered with non-conducting material. Although there are some losses when using superheated steam on account of the heat radiation, they are very much smaller, because the loss of heat from superheated steam has lower calorific value than the latent heat of saturated steam.

Superheated steam has a greater volume per unit of weight than saturated steam at the same pressure; hence one advantage,

and the higher the temperature the greater this advantage. At various pressures and temperatures the increase of volume may be taken from the following Table I:

TABLE I.

Pressure.	390 degrees F.	570 degrees F.	750 degrees F.
70	1.1	1.33	1.57
115	1.06	1.29	1.52
170	1.02	1.24	1.46

Table I shows that the higher the pressure is, the smaller the increase of volume, and it is proved from practice that the advantage with lower pressure is indeed greater in proportion than with higher pressures.

The question may arise whether the increase of volume does not require more additional heat than the benefit derived from it is worth. To show this clearly, Table II has been prepared, expressing how many British thermal units less are required to produce 1 cubic foot of superheated steam than of saturated steam at the same pressure. For various pressures and temperatures the total heat per cubic foot is as follows:

TABLE II.

Pressure.	Saturated.	390 degrees F.	570 degrees F.	750 degrees F.
70	233	219	192	175
115	350	337	297	267
170	492	485	432	398

i. e., to produce, for example, 1 cubic foot of steam at 115 pounds pressure and a temperature of 570 degrees Fahrenheit,

$$\frac{350 - 297}{350} = 15 \text{ per cent.}$$

less heat is required than to produce 1 cubic foot of saturated steam at the same pressure. With saturated steam engines, 20 per cent. to 25 per cent. of admitted steam is condensed during the admission period; consequently the practical steam con-

sumption is very much in excess of the theoretical. Superheated steam does not condense during this period if sufficiently superheated; hence another advantage.

The economy effected by using superheated steam in engines is very remarkable, and, acknowledging this fact, a great number of steam users all over the world superheat the steam, although in many cases only a few degrees, yet a considerable saving in steam and coal is always the result. To obtain the full benefit, the required temperature of steam is 660 degrees to 700 degrees Fahrenheit, and to stand this temperature the engines must be specially designed. It is not sufficient to use mineral oil with a very high flash point, and anyone who tries to supply an existing engine of any kind with steam at that temperature will have a very unpleasant experience, even when using the above-mentioned oil.

The introduction of superheated steam into engines largely influences the expansion of the heated parts. Engines always gave great trouble when the distribution of metal in the cylinders was not uniform, as parts with more metal expanded most, and forced the cylinder walls towards the inside, and made the cylinder out of shape. When using liners in the cylinders, they were squeezed in at the ends, decreasing the diameter, and jamming the piston body if sufficient clearance was not provided. With steam jackets heated with steam of 500 degrees Fahrenheit, the lubrication ceased as the cylinder walls became too much heated, consequently it was found necessary to do away with jackets, or, if jackets were already provided, not to pass steam through them. Pistons constructed on the Ramsbottom type always worked satisfactorily, except in the case of pistons fitted with steel springs, when they were in contact with highly superheated steam. Any kind of gun metal gets brittle after a very short time, therefore valves, seats and all parts in direct contact with superheated steam must be made of cast iron or other suitable mixture. Copper also loses about 40 per cent. of its strength at that temperature, consequently copper bends in pipes are not practicable. The best material for piping has proved to be wrought iron and steel, each pipe being as long as possible, to have the

least number of flanges. For long, straight pipe connections, provision must be made to meet the expansion, which is, at 700 degrees Fahrenheit, 0.0037 of the length, so that, for example, 100 feet of pipe extends 0.37 of a foot, or nearly 4½ inches.

Glands and stuffing-boxes at first frightened users, so the engines were constructed single-acting to avoid the use of glands, but no serious difficulties have arisen on that account. It is advisable to place the stuffing box as far as possible from the cylinder end to keep it well away from the hottest parts, and to allow of as much radiation as possible. Sufficient clearance in the neck bush should be made to allow for the expansion of the piston rod, and no metal with a melting temperature below that of the steam should be used.

Valves and valve gears are influenced in the same way by superheated steam. Valves containing many ribs or different thicknesses of metal (in section), such as plain slide valves or Corliss valves of the usual construction, are not suitable for high temperatures. A Corliss valve of medium size will stand 480 degrees to 500 degrees Fahrenheit, but no more, and the latter temperature very seldom. The smaller the plain slide valves are, the higher the temperature they will stand; large slide valves will hardly stand even slightly superheated steam if no provision is made for forced lubrication of the valve face.

Piston valves have proved to be most suitable for the highest temperature, owing to their uniform distribution of metal; but even with this sort of valve certain experience is necessary to get them in good working order. With ground valves, the ribs holding the boss for the valve spindle must not begin within the working surface of the valve, but have to be placed beyond that, because they expand and make the valve polygonal. The valves must be ground in other liners to those in which they are to work in the engine; the former liners have to be smaller in diameter to secure more clearance, to provide for the expansion of the valves; all ribs must be placed beyond the working surfaces of the valve. The cylinder expands in length more or less than the steam chest, causing thereby deformation of the latter, which must be carefully considered in design. It is best to work

the valves in liners fixed in the cylinder and with a small clearance, sufficient to allow for the deformation of the steam chest. With this construction, it is, of course, necessary to make steam-tight joints between the several ports, and this is best done by stepping the liners and seats and using narrow asbestos rings for each step. The liner is then forced on to the small seats by set screws in the cover, these asbestos rings making a lasting joint. Long valves cast in one piece become scored, whether they are cooled from inside with exhaust steam or not; consequently all valves should be made as short as possible. Rings and springs in valves cannot be recommended, as the steam comes behind the rings and increases the pressure, causing friction, and, therefore, increased oil consumption. As it is impossible to rely on tightness of piston valves, they must be made as small in diameter as possible. It may be stated here that superheated steam can travel at 30 to 40 per cent. higher speed through steam ports than saturated steam, and this fact has to be considered during construction.

Two piston valves working one in the other, as the Rider or Meyer valves, are impracticable for superheated steam. If engines of that type are intended to be worked with superheated steam, each valve must work in a separate chamber.

Double-beat valves can also be recommended as being safe, but they require a special arrangement, which is not always obtainable with every gear. Very often it happens when warming up the engines that the valve spindles get hotter than the gland boxes, and on starting the engine the friction between spindle and stuffing box is greater than the power of the spring, and if the valves are not positively driven, they remain open during the full stroke.

An engine constructed in accordance with the principles just explained is as safe with superheated steam as any other engine with saturated steam. From an experience over several years, it is not necessary to be bound to single-acting engines.

Besides the economy, the use of highly superheated steam has some other advantages, which are also important. It makes the steam consumption nearly independent of the size of the engine,

as a small engine has about the same steam consumption as a large one, as, for example, an 80-horsepower compound condensing engine uses 10.45 pounds of steam at 160 pounds pressure, and a 1,000-horsepower engine uses 9 pounds of steam per indicated horsepower per hour. The use of highly superheated steam does not require high boiler pressures; 160 pounds is the highest to be recommended, as no advantage can be derived by exceeding this. As the amount of heat transmitted from the steam to cylinder walls, and *vice versa*, is much lower with superheated steam than with saturated steam, the whole range of temperature from boiler pressure to vacuum can take place in one or two cylinders, so that the use of a triple-expansion engine does not make the slightest improvement in economy. It is not intended to be understood that the author proposes to do away with all triple-expansion engines; for very large plants their use will be necessary for constructive reasons.

With regard to economy obtained from engines working with superheated steam, the gain is derived from the larger volume of the steam and the doing away with initial condensation.

Generally the steam consumption of modern engines working under good conditions may be taken as follows:

Single-cylinder condensing engines, with saturated steam and a pressure of 90 pounds to 100 pounds per square inch, use 19 pounds to 25 pounds of steam per indicated horsepower per hour, corresponding to 373 to 490 British thermal units per minute. The great difference in temperature between admission and exhaust steam causes much waste by initial condensation, and, consequently, this type of engine especially favors the use of superheated steam. With superheated steam the consumption has been lowered to 13½ pounds to 15 pounds, corresponding to 290 to 335 British thermal units.

Non-condensing single-cylinder engines gave consumptions of 15 pounds to 18 pounds of steam per indicated horsepower per hour, which is about the same consumption as an average compound condensing engine with saturated steam. The non-condensing compound engine decreases the consumption to 14 pounds to 16 pounds per indicated horsepower per hour. The

compound condensing engine is the most economical, and the economy obtained can hardly be reached by a quadruple-expansion engine working at a pressure of 300 pounds. The steam consumption of such an engine, either compound or tandem, at 140 pounds pressure only, never exceeds 10 pounds per indicated horsepower per hour, and usually remains below, many tests having proved 8.5 pounds to 8.8 pounds consumption per indicated horsepower. To utilize better these temperatures, and to work with various loads with safety and nearly uniform economy, Mr. Schmidt has introduced the receiver heater with automatic valve. The idea is to keep a steady mean temperature of cylinder walls not higher than will make the lubrication unreliable for different rates of expansion.

A few words may be said with regard to the cost of a superheated plant. Superheated steam engines use on an average 30 to 40 per cent. less steam than saturated steam engines of the same type. Consequently boilers can be made 30 per cent. smaller, and the difference in price will nearly cover the cost of the superheater. For the same steam consumption the superheated steam engine is cheaper, as it may be worked with a lower boiler pressure, and it is simpler, *i. e.*, instead of a compound engine with saturated steam, a single-cylinder engine with superheated steam may be used, giving the same or better results than the former.

With regard to oil consumption, it was found not to be more than that of an ordinary saturated steam engine. For example: A 120 indicated horsepower engine used in 24 hours 4 pounds of oil, and a 300 indicated horsepower Corliss compound engine 2.2 pounds in 10 hours for both cylinders.

In view of the great advantages of steam superheating and the great number of engines running at present satisfactorily, it is astonishing that a few failures have caused prejudice amongst some engineers, who make the general introduction of the use of superheated steam very difficult. It will be worth mentioning that the results of a great number of trials have always proved a great saving in steam and coal, and even with small plants and simple piston-valve engines, almost the same good economy is

obtainable as with large engines with most exact valve gears. It is therefore recommended that superheated steam should be used in connection with all engines; the only question to be settled is the degree of superheat, which largely depends on local circumstances and the construction of the engine, and this matter should be left to the judgment of an experienced engineer.

THE DISPLACEMENT AND DIMENSIONS OF SHIPS.

APPROXIMATE RULES FOR THE DETERMINATION OF THE DISPLACEMENT AND DIMENSIONS OF A SHIP IN ACCORDANCE WITH A GIVEN PROGRAMME OF REQUIREMENTS.

Paper read before the International Engineering Congress, Glasgow, 1901. Section IV: Naval Architecture and Marine Engineering.

By J. A. Normand.

The problem which forms the subject of this paper is the one most frequently proposed to the naval architect; but, although the technical literature increases constantly, he would vainly search, in the vast amount of documents at his disposal, for any simple method of solving it. We have one, it is true, but it is not simple, and consequently it is very seldom used. It is founded on the equation of displacement, of the third degree at least.

There exists another method, this one of extreme simplicity, although derived from the same equation of displacement. It offers the further advantage of showing explicitly the relative influence of each part of the program on the final result.

I will try to explain it as clearly as possible, since, although used by some naval architects, it is probably unknown in this country.

When the plans for a new vessel are to be laid down, the surest and simplest process is to take as a type one or more vessels differing as little as possible from the one to be designed—preferably existing vessels, all the data, partial weights and results of which are well known, so that the calculations may be based on facts, and not on hypothesis—and to work out the changes required by the slight differences between the programs of the old and the new ship. The possible errors are limited in that case to those that may be committed on slight differences.

If the vessel to be designed is a cargo or passenger boat or a yacht, size forms generally part of the program. Not so in a war vessel, where size and displacement must, in most cases, be reduced to a minimum. This paper deals more especially with war vessels, although the proposed rules may be used with great advantage for all kinds of ships.

We will first suppose that the speed of the vessel chosen as type is not altered, but that weights only are added or suppressed. What will be the displacement of the new ship, supposing her to be exactly similar to, and differing only by scale from, the type vessel, the water line remaining at the same relative height in order that the fineness of lines may not be altered?

It is clear that the difference of displacement must be much larger than the difference of weights, as calculated for the type. If, for instance, the difference of weights is positive, and equal to 300 tons, should the vessel remain unaltered, she would settle down; her resistance would be increased, her lines fuller, her seaworthiness reduced, and so would the speed and the steaming distance. Accordingly, the dimensions must be increased; but as they increase, so will the resistance, the horsepower, the weight of hull, machinery, and coals; and this further increase of weights will require a further increase of dimensions and displacement.

Now, is there a simple relation between the weights first added to the type vessel and the ultimate increase of displacement? There is.

According to an approximate law first given in 1885,* the demonstration of which will be found in the Appendix: "The plus or minus difference of displacement must be equal to the plus or minus difference of weights, as calculated for the vessel chosen as type, multiplied by a coefficient K which can be exactly determined and is nearly constant for all classes of vessels (its mean value being about 3.6), in order that the general conditions of the program may be fulfilled.

Knowing by this very simple rule the approximate displace-

* "Etude sur les Torpilleurs," by J. A. Normand. An English translation of this pamphlet was published by the United States Office of Naval Intelligence in "Papers on Squadrons of Evolutions," June, 1886.

ment of the ship to be designed, it is easy to calculate the dimensions, horsepower, weights of hull, machinery, coals, &c., by reference to the same elements in the type vessel.

At the same time, if the value of K has been calculated for the different types of vessels, in any navy, the naval architect is able to know very quickly whether the new program can be carried out without radical changes, such as adopting stronger materials and reducing the scantlings, increasing the immersion and reducing the relative height of freeboard, adopting lighter machinery and boilers, or reducing the fineness of the lines, which can be done within certain limits, by a slight increase of power, provided the relative propulsive surface be augmented.* The new method enables us to estimate the consequences of any of these modifications on the size of the vessel to be designed.

The rule does not apply so well to first-class battleships and cruisers, that is to say, the coefficient must then, as experience has shown, be lowered down to 2.8 and 2.5 because the law of similitude, on which it is based, does not hold good in that case. The transverse dimensions of those very large vessels remain generally constant, since the draught of water and the statical stability cannot be increased, the difference in size depending almost entirely on the difference in length.

Before going further, it may be well to show how easily this rule may be applied.

Let me take as a type a cruiser resembling somewhat the *Diadem*, with Belleville boilers, and suppose the particulars of this type to be:

Length, feet,	435
Beam, feet,	69
Mean draught, feet and inches,	25–3
Midship section, square feet,	1,430
Displacement, tons,	11,000
Maximum speed at the above displacement, knots,	20
Corresponding indicated horsepower,	16,500

* See "Sur les Advantages que presente pour les Navires de Guerre, la combinaison d'une faible acuite et d'une grande surface propulsive." ("Bulletin de l'Association Technique Maritime," No. 12, 1901.)

Let the partial weights be:

1. *Weights Varying as the Displacement.*

Hull, complete with accessories, but without wood and copper sheathing, tons, ...	4,200

2. *Weights Varying as the Displacement.*

Wood and copper sheathing, machinery, boilers, &c., coals necessary for steaming a certain distance at a given speed and for all auxiliary services, crew and effects, provisions, fresh water, boats, tons, . .	5,500

3. *Weights Independent of the Displacement.*

Guns, ammunition, turrets and accessories, hoists, block-house, torpedoes and tubes, tons, ...	1,300
Total, equal to displacement, tons, . . .	11,000

$$K = \frac{11{,}000}{11{,}000 - 4{,}200 - \frac{2}{3}\,5{,}500} = 3.51.$$

Now, what would be the displacement and dimensions of a similar vessel where—

1. Small-tube boilers are substituted for Bellevilles, the speed, steaming distance, thickness and distribution of armor, weight of guns and ammunition, &c., remaining the same?

2. Cylindrical boilers substituted for Bellevilles, the other conditions, speed, &c., as above, remaining the same?

3. Small-tube boilers substituted for Bellevilles, the weight of guns, &c., reduced by 35 tons, the weight of armor reduced by 20 tons, and the steaming distance increased by 30 per cent. (assuming the weight of coals to be 2,000 tons at 11,000 tons displacement), the speed remaining the same?

FIRST PROBLEM.

The weight of small-tube boilers (Normand's, for instance, with tubes $1\frac{1}{2}$-inch outside diameter, instead of $1\frac{1}{4}$-inch in destroyers) is about 20 per cent. heavier per square foot of grate than Belle-

villes, but the combustion for the same unit may be larger in cruisers by 70 per cent. (34 pounds per square foot of grate; that is to say, less than one-half the rate of combustion in destroyers, instead of 20 pounds), the evaporative duty being the same, so that the relative weight of small-tube and Belleville boilers per indicated horsepower is about

$$\frac{1.20}{1.70} = 0.70$$

The weight of Belleville boilers and fittings in the *Diadem* (of 16,500 indicated horsepower, as in the type) being 748.4 tons, the saving in weight would be $(1 - 0.70)\ 748.4^{t} = 225$ tons.

Accordingly, the displacement would be reduced by

$$225^{t} \times 3.51 = 790 \text{ tons},$$

and would become 10,210 tons.

Ratio of dimensions of the hull

$$\sqrt[3]{\frac{10,210}{11,000}} = 0.9754$$

$$\text{Power: } 16,500 \left(\frac{10,210}{11,000}\right)^{\frac{2}{3}} = 15,700 \text{ I.H.P.}$$

The weight of coals is reduced in the same ratio as the power, to keep the same steaming distance.

Weight of machinery, boilers, propellers, &c.: This weight being $1,436.7^{t}$ in the *Diadem*, we have

$$(1,436.7^{t} - 225^{t}) \left(\frac{10,210}{11,000}\right)^{\frac{2}{3}} = 1,153 \text{ tons.}$$

SECOND PROBLEM.

From Sir John Durston's paper* it appears that the saving in weight of boilers and machinery due to the substitution of Belleville for cylindrical boilers, working at a lower pressure, is, at least, 650 tons, the maximum rate of combustion being 20

* Transactions of the Institution of Naval Architects, 1898.

pounds per square foot of grate for Belleville and 30 pounds for cylindrical boilers.

The relative importance of the extra weight is too great in this case to allow the use of formula (2). We must take formula (7).

$$K = \frac{11{,}000}{11{,}000 - 4{,}200 - \frac{2}{3}(5{,}500 + 650)} = 4.073.$$

The displacement of the type increases by

$$650^t \times 4.073 = 2{,}647^t \text{ and becomes } 13{,}647 \text{ tons.}$$

Ratio of linear dimensions of the hull:

$$\sqrt[3]{\frac{13{,}647}{11{,}000}} = 1.075.$$

$$\text{Power: } 16{,}500 \left(\frac{13{,}647}{11{,}000}\right)^{\frac{1}{2}} = 19{,}060 \text{ I.H.P.}$$

The weight of coals being increased in the same ratio to keep the same steaming distance.

Weight of machinery, boilers, propellers, &c.:

$$(1{,}476.7^t + 650^t)\left(\frac{13{,}647}{11{,}000}\right)^{\frac{1}{2}} = 2{,}410 \text{ tons.}$$

It is prudent, especially when the extra weights are very important, to verify that no error has been made in the calculation. Here we have for the new ship:

1. Weights varying as the displacement:

	Tons.
$4{,}200 \times \frac{13{,}647}{11{,}000}$	5,210
2. Weights varying as displacement—$\frac{2}{3}$	
$(5{,}500^t + 650^t)\left(\frac{13{,}647}{11{,}000}\right)^{\frac{1}{2}}$ . . .	7,110
3. Weights independent of the displacement, .	1,300
Displacement of the new vessel, . .	13,620

instead of 13,647 tons. The difference is of no importance.

From the above it appears that the displacement of a cruiser of the type selected varies approximately from 10,210 tons to 13,647 tons; in other words, increases by one-third according as she has small-tube high-pressure or cylindrical ordinary boilers, working at a lower pressure, all the other conditions of the program—speed, weight of guns and ammunition, thickness and distribution of armor, steaming distance, &c.—remaining the same.

THIRD PROBLEM.

Extra weights as calculated for the type:

	Plus.	Minus.
Boilers, as above, ...	...	225^t
Guns and ammunition, ...	...	35
Armor, ...	...	20
Coals, $2{,}000^t \times 0.30$, ...	600^t	...
	600^t	280^t

Increase of weights, 320 tons.

The displacement would increase by

$$320^t \times 3.51 = 1{,}123 \text{ tons},$$

and become 12,123 tons.

Ratio of linear dimensions of the hull:

$$\sqrt[3]{\frac{12{,}123^t}{11{,}000}} = 1.033.$$

$$\text{Power: } 16{,}500 \left(\frac{12{,}123}{11{,}000}\right)^{\frac{2}{3}} = 17{,}600 \text{ I.H.P.}$$

Weight of machinery, boilers, &c.:

$$(1{,}436.7^t - 225^t) \left(\frac{12{,}123}{11{,}000}\right)^{\frac{2}{3}} = 1{,}292 \text{ tons.}$$

Weight of coals:

$$2{,}000 \times 1.30 \left(\frac{12{,}123}{11{,}000}\right)^{\frac{2}{3}} = 2{,}775 \text{ tons.}$$

FOURTH PROBLEM.

We will now suppose that the only difference in the program of requirements of the vessel to be built and the above typical

cruiser consists in an increase of speed of 1 knot. The fineness of the lines of the type must be increased, which cannot be done generally without reducing the displacement to suit the new speed, so that the coefficient of performance—

$$\frac{\text{Midship section} \times (\text{speed})^3}{\text{I.H.P.}}$$

should remain the same, and the power must be augmented, for the type, in proportion to the cube of the speed.

The reduction of displacement due to increase of fineness is, by formula (14),

$$\Delta D_s = -0.037 \times (1{,}430)^{\frac{2}{3}} \times 1.00\, K' = -325 \text{ tons},$$

and by formula (15),

$$\Delta D_s = -\frac{0.0286 \times 1{,}430 \times 435 - 11{,}000}{20} = -339 \text{ tons}.$$

We will adopt a mean value of -330^t.

The weight of machinery, boilers, &c., P_m of the type being equal to $1{,}436.7^t$, we have by (9)

$$\text{Displacement of the new ship} \begin{cases} D' = 11{,}000 + 2.51 \times 330^t + 3 \times \\ 3.51 \times \frac{1}{20} \times 1{,}436.7 = 11{,}828 + 3 \times \\ 3.51 \times \frac{1}{20} \times 1{,}436.7^t = 12{,}585^t. \end{cases}$$

Ratio of displacement of the new ship and of the type altered to suit the new speed: 21 knots.

$$\frac{12{,}585}{11{,}000 - 330} = 1.180.$$

Ratio of linear dimensions

$$\sqrt[3]{1.180} = 1.057.$$

Ratio of indicated horsepower and of weight of machinery and boilers by (12)

$$\left(1 + \frac{3}{20}\right)(1.180)^{\frac{1}{3}} = 1.284.$$

From the above we see that, in a cruiser of the type considered, an addition of 1 knot to the 20 knots of the type vessel leads to an increase of about 18 per cent. in the displacement, and of 28 per cent. in the power, the thickness and distribution of armor, steaming distance at a constant speed, and weight of guns, ammunition, &c., remaining the same.

The increase would be still greater if the steaming distance were partly measured at a speed proportional to the maximum. It ought to be so, since it is useless to give a very high speed to a ship if she is never to make use of it. No quality is more expensive than speed.

The few problems which we have solved by the new method are sufficient to show how easily it may be applied. It elucidates very simply a question which most people, and even some naval architects, do not clearly realize, the extreme importance of lightness in a warship. How often have we not heard during that everlasting discussion about cylindrical *vs.* water-tube boilers, that "to save a few hundred tons weight it is dangerous to change a well-known type of boiler for a more expensive one, requiring far greater care in manufacture and working." Even if it were so, it ought to be known that the saving is not those few hundred tons weight, but about $3\frac{1}{2}$ times this amount.

The immense advantages resulting from a reduction in the weights of war vessels will certainly lead sooner or later to the adoption not of small water-tube, but of mean water-tube boilers of some type or other capable of standing a high rate of combustion. Even this alteration will not be sufficient if the race for speed continues.

Steel of high tensile strength will be needed for the hulls of large vessels; but the greater part of the advantages to be derived from its use will be lost until equally strong steel, not hardening when riveted hot, can be commercially and surely produced.

In this paper I have dealt only with large vessels, the speed of which corresponds always to the descending part of the curve of the coefficients of performance. The principles laid down

may equally well be applied to small high-speed vessels, such as destroyers and torpedo boats; but it must not be forgotten that their maximum speed always corresponds to the ascending part of the curve, so that the fineness of the lines need not be altered when the maximum speed changes, and that the power may be proportioned to the square of the speeds.

We have seen that, on the contrary, in large vessels the power varies as the cube of the speed when the fineness is altered to suit the new speed, or to a higher power if the fineness remains the same. Extreme speed is relatively less expensive in a small vessel than in a large one.

THE HYDRAULICS OF THE RESISTANCE OF SHIPS.

By Edgar C. Thrupp, A. M., Inst. C. E. Paper read before the International Engineering Congress, Glasgow, 1901. Section IV; Naval Architecture.

The object of this paper is to investigate the discovery of a phenomenon in the laws of motion of water which has an important bearing on the variations in the resistance of ships at different speeds, as well as upon the problems which civil engineers have to deal with in navigable channels and tidal estuaries.

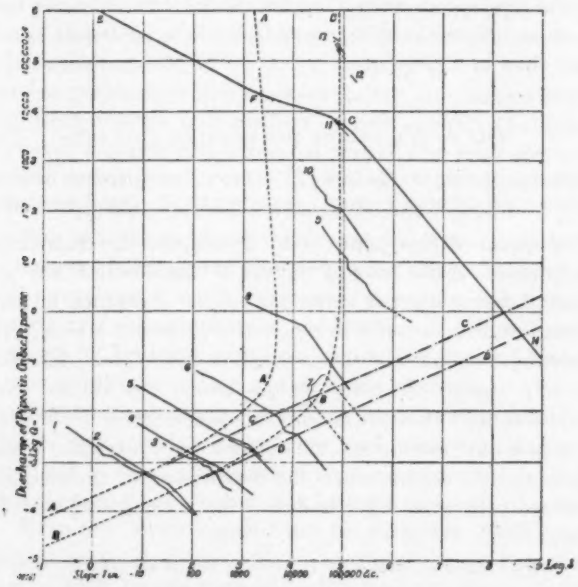
Briefly stated, the phenomenon which the author has discovered is that there is an enormous divergence from the laws of stream-line motion as enunciated by Poiseuille, Osborne-Reynolds, and others, when the dimensions of the channels or pipes are such as to have hydraulic radii exceeding 1 inch or 2 inches.

It is well known that water moving in small pipes experiences frictional resistance which is approximately proportional to its velocity. At a certain "critical point" the nature of the motion changes, and at higher velocities the resistance varies as V^3 V^4 or thereabouts, and at still higher velocities the ratio becomes more constant and the resistance is generally proportional to $V^{1.8}$ to V^2.

Professor Osborne-Reynolds investigated the phenomenon of the "critical point," and in the "Philosophical Transactions of the Royal Society" he laid down the law that the critical veloc-

ities for pipes of different dimensions varied in simple inverse proportion to the diameters or hydraulic radii.

The author has proved by experiment that this "law" relates to an extremely limited range of conditions, if it can be regarded as a "law" at all. The error is equivalent to an assumption that two given points on a line prove that line to be straight, whereas it is obvious that it might be a curve, and in the present case the



actual line is of hyperbolic form, and Professor Reynolds' "law" represents a tangent at a certain point on one limb of the curve, and it so happens that the other limb of the curve is of far greater practical importance.

The author's experiments show that when the hydraulic radii are greater than 2 inches, the critical velocity increases with the hydraulic radius, and he has traced the critical velocity phenomenon and the stream-line law of resistance from the conditions

of flow in a pipe ¼ inch in diameter up to those of the lower reaches of the Mississippi. In the latter case he finds the critical velocity in channels 60 feet deep to be many thousand times as much as indicated by the Osborne-Reynolds "law."

The accompanying diagram, plotted to a logarithmic scale, indicates some of the chief experimental data bearing on this question.

The horizontal scale represents the logarithm of the hydraulic gradient (log. S) expressed as the co-secant of the angle of inclination, and the vertical scale represents the logarithm of the discharge (log. Q) in cubic feet per second. In the case of open-channel experiments, the discharge is calculated as that of a circular pipe of the same hydraulic radius as the channel under observation. For any particular pipe or channel the results will appear in a straight line on a slope of 2 horizontal to 1 vertical, where the resistance varies as V^2, and on a slope of 1 to 1, where the resistance is simply proportional to the velocity, and so on.

Commencing at the bottom of the diagram, the various lines indicate the following data:

1. ¼-inch pipe,	Osborne-Reynolds.
2. Ditto,	Darcy.
3. ½-inch pipe,	Thrupp.
4. Ditto,	Darcy.
5. Ditto,	"
6. 2½-inch pipe,	J. Leslie.
7. Experimental trough,	Thrupp.
8. 15-inch pipe,	"
9. Head race of mill on the River Kennet,	"
10. River Thames,	"
11. River Irrawadi,	R. Gordon.
12. Rio Las Palmas,	Revy.
13. River Mississippi,	1882 Commission.

Numerous indications of the phenomenon appear in other published records of hydraulic experiments, and they have invariably been regarded as erratic by the authors of the experi-

ments, or their critics, and in no case can the author find the slightest suggestion of the possibility of the critical point occurring at such high velocities.

The results of the trough experiments (No. 7) are not shown in detail on the diagram, as they are complicated by differences of hydraulic radius, but the two lines shown indicate the general result.

The critical region is located on the diagram between the dotted lines *A A A* and *B B B*, whereas, by the Osborne-Reynolds "law," it would be somewhere about *C C* and *D D*.

The line *E F G H* represents an example of the complete law of flow for a channel of constant hydraulic radius. The portion *E F* would be on a slope of 1.8, or 2 to 1, and the portion *G H* on a slope of 0.8, or 0.9 to 1, whilst the intervening portion *F G* is a reverse curve, having a slope of 3 or 4 to 1 in its flattest part.

A confirmation of the author's conclusions is afforded by a study of the nature of channel beds, and the scouring power and silt-carrying capacity of water flowing at various depths. The depths and velocities which occur in channels where the beds are accumulating very fine silt agree closely with the critical velocities arrived at from the surface slope and velocity measurements. The conclusion is obvious, namely, that fine silt is dropped in stream-line currents and scoured when the velocity rises above the critical point and changes the flow to sinuous motion. Baumgarten was one of the first to notice (on the *Garonne*) that silt rose when the motion of the water became sinuous. It has since been frequently noticed by others, but no one has hitherto shown the connection of this with the critical-point phenomenon.

Mathematical theories of the velocities required to move solid particles in water have been advanced from time to time, and have been in some slight degree confirmed by experiments on a small scale under certain conditions, but they entirely fail to agree with the observed phenomena of scour in large channels, for there are innumerable instances where the velocities at the bottom of the channels are sufficient, according to mathematical

theories, to roll along large cubical boulders, whereas, in fact, they hardly disturb fine silt or sand.

No mathematical theories hitherto advanced can account for these critical-point phenomena, because the assumptions upon which they are based have not been ascertained by experiment.

The problem of the resistance of ships is intimately connected with this critical-point phenomenon and also with certain wave-motion phenomena, which the author has also found experimentally to differ from the views advanced by some eminent writers.

The theory of steamship resistance has undergone many changes and much discussion, and valuable contributions to our knowledge of the subject have been made by Beaufoy, Sir J. McNeill, Poncelet, Rankine, Scott Russell, Bramwell, W. and R. E. Froude, Kirk, Mansel, Denny, and others. The outcome of all these investigations is not a triumph for "Hydraulics as an Exact Science."

The generally accepted conclusion is that the experimental model system of estimating a ship's resistance according to the mode of comparison enunciated by W. Froude on the principles of "similar motions" laid down by Newton, is the best system yet known; but even that method requires some "doctoring" to make it fit in with the results of actual trials. Why is it so? The answer is, that the motions of the water past the model and past the ship at the so-called "corresponding speeds" are not precisely "*similar motions*" owing to the critical velocity laws which rule the motions within the limits of speed at which such trials are usually made. It is customary to circulate all the known sources of resistance on some sort of a scientific basis, and to call all the rest "wavemaking resistance," and this phrase is used to smother a great lack of knowledge.

The experiments of Beaufoy and Froude on the "skin friction" of planks or plates towed through water supplied data which have been largely used for estimating the frictional resistance of water against the sides of ships. Certain allowances may be made to take into account the effect of the following wake in reducing the friction in the after part of the vessel, in accordance with the results of Froude's experiments; but the assumptions

which are made in applying these data to the cases of actual ships are not entirely warranted by facts ascertained in other departments of hydraulic science. For instance, experiments on pipes and open channels show that it is erroneous to assume that the friction per square foot of wetted surface is necessarily the same in all cases where the velocity of water flowing against it is the same. The actual amount of friction depends on the dimensions of the channel and the nature of the motion of the water as well as upon the velocity. That this is also the case as regards ships is only a natural conclusion, and there is strong evidence in favor of this conclusion being derived from the results of certain experiments. There is a tendency to attribute all obscure phenomena in ship resistance to "wave action" of some sort; whereas it may be that in some cases the appearance of the waves is only an effect, and not the cause, of the phenomenon. Not a few ships have had their performances improved by the process of cutting them in half and inserting a parallel body-lengthening piece in the middle. Canal barges of similar cross-section and of different lengths have long been known to present very similar resistances, and the recent experiments of De Mas in France have conclusively proved that large differences in length may make practically no difference whatever in the resistance. Froude's experiments with models having various lengths of parallel body showed great fluctuations in resistance coincident with the existence or absence of the crest of a transverse wave near the stern of the model, and he concluded that the fluctuations of resistance were due to the positions of the accompanying transverse waves. But what do these positions depend upon?

It is frequently asserted in text books that water passes a ship in "stream lines," after the manner of the striped films in Professor Hele-Shaw's recently-published experiments. The author believes that there is a serious fallacy underlying this theory. In passing through a shallow and restricted channel in a steamer, the striking phenomenon may be observed of the water near the banks first showing the approach of the vessel by sinking in level. This often occurs abreast of the bow of the vessel, and

indicates that there is a diagonal undercurrent from the point where the sinkage occurs towards the stern of the vessel, where there is a natural depression in the water level. The water to fill the depression is thus drawn from the direction where the nearest still water exists (undisturbed by the forward movement of the vessel). The well-known action of vessels moving in the Suez Canal sucking or drawing moored vessels towards themselves is due to the lateral component of this diagonal undercurrent. In the open sea a similar undercurrent no doubt occurs, conveying water from the area in front of the diverging bow waves to the area of depression behind the stern of the vessel, and forming a virtual bottom to the waterway upon which the waves accompanying the vessel roll. The upper margin of the undercurrent is constrained to settle down to the depth corresponding to that required by a trochoidal wave for traveling at the speed of the vessel. It is not necessary to assume that there is a hard-and-fast line determining this upper margin, but the effect is practically equivalent to that of such a line. Following up this theory, the fact that all the transverse waves following the vessel travel at the same speed has to be accounted for, in view of the facts that their heights gradually diminish towards the rear of the group, and that Scott Russell proved that the speed depended upon the depth measured from the crest of the wave. It is only necessary to meet these facts by assuming that the upper limit of the undercurrent becomes deeper towards the rear of the group of waves, and there is nothing inconsistent with this assumption in the observed facts. The curious effect produced by the movement of a boat in shallow water when a speed is reached corresponding to the wave speed for the total depth of the water, was observed in Scotland about eighty years ago, particularly by Sir John McNeill, also later on by Scott Russell, and recently, with Danish torpedo boats, by Captain Rasmussen. The particular feature of these observations bearing on the present point is that a group of following waves is possible up to a certain speed, and then a point is reached where only a single wave is possible, the depth being insufficient to provide any undercurrent space under that wave, or to enable any waves of

less height to follow behind. Under such conditions the boat rides on top of the single wave, and the undercurrent work is done entirely by the orbital motion of the particles forming the lower part of the single wave.

In this connection the author must refer to the views expressed by several eminent writers on the movement of groups of waves.

Sir George Stokes, Professor Osborne-Reynolds, and Lords Rayleigh and Kelvin have held that the speed of a group of waves is necessarily half the speed of the individual waves forming the group, and Lord Kelvin expounded this view in a lecture to the Institution of Mechanical Engineers, at Edinburgh, in 1887. It may seem presumptuous to dispute the conclusions of such eminent mathematicians, but it is nevertheless necessary to do so. In the first place, it must be admitted by everyone that the train of transverse waves following a ship is a group of waves; and, secondly, it requires but little observation to see that this group, and also all the individual waves forming the group, do travel at the same speed as the vessel. Further, the author has proved by direct experiment in the trough used for his critical-point observations that a group of waves, closely resembling those following a boat, can be produced without difficulty, and that the group travels at the same speed (or an average speed) as the individual waves, without any of that dying away in the front or formation of fresh waves in the rear which Lord Kelvin mentions. These waves, however, are of the trochoidal type, which Scott Russell called "great primary waves," and the distance between their crests has not that same peculiar significance which is a feature in "groups" of the type investigated mathematically by the authorities named; in fact they are "isolated waves" following one another, and in the author's experiments the distances between the crests increased as the group traveled, each wave moving at the speed due to the depth from its crest to the bottom of the channel. It is clear that the only condition necessary to insure the maintenance of such a group without alteration of the distances between the crests, is the existence of a virtual false bottom to the channel, traveling with the group

and curved vertically parallel to a line passing through the crests of the waves. The return undercurrent serves this purpose.

Another point upon which there is much confusion in text-books is the question of the velocity of movement of the water and the direction of the currents past the ship. From what has already been said about the diagonal return undercurrent it will be clear that the ordinary stream-line idea is untenable, and it should be clearly borne in mind that the bulk of the water disturbed is only moved a short distance, and at a velocity much below the speed of the ship. For instance, the velocity at which the water is thrust aside by the bows will be roughly equal to $-$ speed of ship $\times \frac{\text{half width of ship}}{\text{length of entrance}}$.

When the lateral thrust is finished, that is, at the end of the "entrance" the actual velocity of the water is reduced, or almost entirely checked, and the energy imparted to it is passed on to other parts of the water forming the complicated return current as well as the waves. Most of the water which has not actually lain in the path of the ship, but has to make way for that thrust aside, will be moved short distances at velocities still less than the lateral-thrust velocity of the bows, but, at the same time, quite considerable.

The author believes that the skin-friction resistance of ships is generally less than is supposed, and that a large proportion of the "residual resistance," together with the greater part of the distinctive characteristics of progressive speed trials, are due to the critical-point laws met with in the complicated return undercurrents, and that the transverse waves are intimately connected with these currents.

No true system of comparison between model experiments and actual trials can be established unless the critical-point phenomenon is thoroughly studied, and at present the materials for such study are not in the author's possession.

It is quite probable that the vast store of experimental data in the possession of those who have carried out model experiments and also progressive-speed trials might, if studied from the right point of view, yield some valuable indications of the real facts;

but special experimental work will have also to be undertaken to make the investigation completely satisfactory. There is good ground, however, for hoping that a sound basis of comparison of the performances of ships may yet be arrived at. At all events, it seems certain that a system of comparison may be developed on real scientific data, which ought to supersede the present old-fashioned Admiralty coefficients.

THE REPAIR OF THE TORPEDO-BOAT DESTROYER *SALMON*.

One of the most interesting ship-repair jobs yet carried out is that now being completed at Sheerness dockyard, of which Captain Gerald C. Langley is captain-superintendent. This work is in connection with the reconstruction of the torpedo-boat destroyer *Salmon*, which, as a result of a collision with one of the passenger steamers of the Great Eastern Railway, was almost cut in two parts transversely, one-half of her length, the bow part, being driven out of line to the extent of 15 feet at the stem, listed to starboard to the extent of 5 inches in 12 feet, while the keel was from 6 inches amidships to 21 inches at the stem lower than the stern part, which remained unaffected. Such a contortion in all three possible directions is almost unique, for, although there have been cases of torpedo-boat destroyers having their bows stove in concertina-wise by running against some obstacle of greater resistance than the ductile steel of which they have been built, there have been no cases where damage has been so extensive without complete loss; and similarly there have been few instances where the metal has been called upon to stand such severe stress, and has proved so satisfactory. This demonstration of the extent of fatigue which steel of suitable quality will survive is peculiarly opportune at a time when discussion on this point is raised, owing to the unfortunate accident to the *Cobra*.

The *Salmon* was built by the Earle Company, of Hull, in 1895, and is one of the original fleet of 27-knot boats. She is 200 feet long, 19 feet 6 inches beam, and at 5 feet 4 inches draught displaces 264 tons. She is fitted with twin-screw triple-compound

engines, steam being supplied by Yarrow boilers, eight in number, placed in two compartments, each having four boilers, with the stoking platform in the center, the boilers being seated with their backs to the watertight bulkheads. The four funnels are placed two close together in the center and one forward and one aft. The point of collision was near to the middle of the foremost boiler compartment, and the port after boiler was driven against its starboard neighbor, while one of the funnels collapsed owing to the buckling of the deck plating. The shell plates at this point vary in thickness from 9½ pounds in the sheer strake to 7 pounds per square foot at the bilge. The frames are 2½ inches by 1½ inches by 2½ pound angle bars, and are at intervals of about 20 inches. The internal keel plate is 7 pounds per square foot. There is the usual transverse bulkhead, and in addition a longitudinal division parallel to, but about 3 feet distant from, the shell plating for the coal bunkers alongside the boiler compartments. These bulkheads are of 4 to 6-pound plates. They are stiffened by 1½-inch by 1½-inch by 1½-pound angles at 20-inch intervals. The deck plating is, beginning at the shell, 9½ pounds, 7 pounds, and 6 pounds in the center. The angle bar connecting the sheer strake and outer plate of the deck is 2 inches by 2 inches by 3½ pounds.

The *Salmon* formed one of the Medway torpedo-boat destroyer instructional flotilla, which was cruising up the North Sea, when the Great Eastern Company's Channel steamer *Cambridge*, on the Hook of Holland route, a short time out from Harwich, ran amongst the boats of the fleet and collided with the *Salmon*, striking her on the port side, almost amidships. In order to save the crew, fifty all told, the bow of the *Cambridge*, practically uninjured, was kept for a considerable time in the indent made in the side of the destroyer; and this, no doubt, explains the peculiar form of the damage. This indent, 5 feet deep and 8 feet broad in the fore-and-aft line, was approximately triangular, the apex being towards the bow of the destroyer. Regarded as a longitudinal box girder, weakened by the serious fracture on one side and on the top and bottom web, it is not difficult to understand why, with a force exerted by the

Cambridge against the tidal resistance on the starboard quarter, the bow part of the destroyer buckled or swerved to the port side out of line with the stern portion of the hull. Not only was the outside skin plating rent violently in a vertical line, but the coal-bunker wall running parallel with it was also fractured, and the athwartship bulkhead parted badly from its angle and gusset-plate connections with the shell plating. The boilers were displaced, and the fracture of the steam pipes resulted in two stokers being most unfortunately scalded to death.

The vessel was brought into Harwich Harbor and beached by the naval authorities, and there an examination of the structure was made and temporary repairs, which enabled the ship to be towed to Sheerness Dockyard, were carried out. Owing to the exposed situation and rough sea at Harwich, the relative position of the parts of the ship before and abaft the damaged portion was continually altering, and it was impossible to do more than fit wood planks across the principal fracture. This enabled the vessel to be towed to Ipswich, where, although there is no dock, a soft mud beach was available, and upon this the *Salmon* was grounded at high water, spring tide.

The main rent extended right down to the bilge, the shell plating being driven through the bunkers to the boiler room. The bottom plating was buckled up athwartship as well as in a longitudinal line. The deck and bottom plates stood the stress remarkably well. The fracture of the deck plating started from the point of junction of the shell and deck plating, and was probably due to the resisting influence of the stringer. This fracture developed with the working of the ship on the beach with each successive tide, and also during the subsequent passage from Ipswich to Sheerness. This point of connection was also the pivot upon which each movement of the structure hinged. The starboard shell plating also buckled, and a double girder was placed along this side, as shall presently be described. Distinct evidences of fatigue were found in the ultimate wave formation of the angles forming the flanges of the girders riveted to both sides of the ship.

Still retaining the wooden planking fitted at Harwich, a deck

stringer plate 3 feet 6 inches broad and about 24 feet long was fitted to extend about 8 feet forward and aft of the 8-foot opening in the side, and a sheer strake or girder, over 30 feet long and 4 feet 6 inches deep, with double angle bars at top and single angle bar at bottom, was riveted by the web to the shell plating forward and abaft the fracture, and was secured to the wooden planking by coach screws. It was also connected by an angle-bar to the 24-foot deck stringer plate. Four girders were fitted in the bottom of the ship, two being passed through the space occupied by the fire grate and ash pan of the Yarrow boilers, and the others in the wing coal bunkers. The bottom skin plating was reinforced with a special plate, to which the girders were riveted, as the ordinary structure would not have stood the concentrated stress of the girders. On the upper deck fore-and-aft girders were similarly riveted. Owing to the extensive buckling, and to the forward part of the ship being at a different level to the after half, the girders had to be in some cases of intercostal form; the webs of the lower girders overlapped, and were riveted to the web of the upper girder, clearing the irregularities of the crumpled-up plates. Some of the plates were cut to suit the run of these temporary girders.

The dimensions of the several girders need not be given; they were settled more by the material available at the dockyard than as a result of the calculation of possible necessities, a large margin being allowed. The main object was to get the ship temporarily repaired with as little delay as possible, so that she could be moved from her more or less insecure position, and docked at Sheerness. It would probably have been better to have placed the side girders inside the hull, especially on the starboard side; as they would then have been in the inside of the angle formed by the two portions of the ship, and would have acted in compression against the prevailing stress; but this was not very easy of realization, owing to the fact that the longitudinal bunkers were only 3 feet broad and the deck openings 12 inches wide. But in addition to the girder outside, there were fitted inside a series of plates of such lengths and widths as the limited space for riveting and the framing would permit.

Thus strengthened temporarily, the ship was towed round to Sheerness Dockyard, not without a great measure of anxiety on the part of those responsible. A wire hawser was placed right round the boat, with a shackle at the bow, so that no stress would be brought on the forward structure. There was a choppy sea, and examination revealed all the evidences of severe working during the voyage. The after boilers in the destroyer were alight for the working of the steam-steering engine and of the ejectors in case the vessel leaked. The steering was not by any means an easy process, owing to the bow of the ship being so much out of line, and owing to the list. This inclination, it is not without interest to note, was to starboard and not to the damaged side; and it is possible that this was due to the swerving of the bow of the ship which caused a departure from the vertical line of the center of gravity and center of buoyancy corresponding to the upright position; the result being a list until the two points were again in a vertical line.

When the vessel arrived at Sheerness, preparations had been made for docking her; but first the true line of the keel had to be determined. This was done by taking the exact draught at many points of the length, by a specially-constructed frame, consisting of a light angle bar, suitably stiffened, and connected at its ends to two uprights, each having draught gauges. By means of the uprights the angle bar was conveyed along the keel from stem to stern, and the draughts indicated the extent of sagging and indents. The results were plotted in a diagram. It was found that immediately forward of the damaged part of the hull the keel was 6 inches below the after-length of the boat, while it drooped toward the stem, which was 1 foot 9 inches down from its original line. As we have already mentioned, it was 15 feet on the port side of the true fore-and-aft line, and the list was to starboard 5 inches in 12 feet. Thus in all three directions the fore part of the hull was distorted. Dock blocks were laid to suit this form; but at the same time the usual keel blocks were set in the central line of the dock true to the ultimate line and level of the keel—a provision which greatly facilitated the subsequent correcting of the alignment of the boat.

Special baulks of timber were laid across the dock between the lines of ordinary blocks to carry the misshapen bow part, and divers were sent down to insure that the ship rested on the seat prepared for her. Three upright cradles were then formed on the transverse baulks. The ship was cut completely in two at the damaged part, and the fore part thus severed was brought into true vertical line by shoring within the cradle, which was subsequently lifted above the level of the ordinary dock blocks by hydraulic jacks, and then gradually slipped over, until the fore part of the hull was in line longitudinally with the after part. The fore part was 3 feet nearer the stern section than the original dimensions required, due, no doubt, to the buckling; and thus it had to be drawn ahead to this extent, and lowered finally on to the central dock blocks originally prepared. The several movements were simple enough, as the weight of the fore part was under 100 tons.

Tensile tests have been made at our request of the steel forming some of these damaged parts, with the following results:

TENSILE TESTS OF STEEL SHEETS (GALVANIZED) OF DAMAGED PLATES, &C., OF H. M. S. "SALMON."

Specimen from—	Application of load.	Thickness of specimen.	Breaking load per square inch of section.	Elongation in a length of 8 inches.
		in.	*tons.*	*per cent.*
Sheer strake	With grain	.221	30.45	18.5
Ditto	Across grain	.238	29.67	14.4
Outside plate	Ditto	.173	28.57	18.7
Ditto	With grain	.176	26.36	17.5
Ditto	Across grain	.143	32.12	14.7
Stringer plate	With grain	.234	26.00	21.6
Ditto	Across grain	.236	26.61	21.4
Deck plate	Ditto	.155	27.03	8.9
Dish keel	With grain	.236	25.68	24.1

As soon as the bow part was brought into position, the work of reconstructing the central part was proceeded with. On an average, 32 feet of the length was taken away and rebuilt; in some strakes 64 feet of the plating was replaced. The two

boilers injured were also largely reconstructed, and the vessel otherwise overhauled.—London "Engineering."

A GRAPHICAL RECORD OF PROGRESS IN STEAMSHIP CONSTRUCTION.

A "Manual of Steel Steamship Construction" has recently been published in Germany, and its author, Herr Otto Schlick, in his introduction presents an interesting chart showing typical steam vessels from the beginning of steam navigation to the present time, all drawn to the same scale. The column is headed by the tiny *Comet* of 1812, named, perhaps, from the train of fire left behind from the chimney when the boat was under way, and the last on the list is the new *Kaiser Wilhelm II*, now being built for the North German Lloyd Steamship Co., which is planned to eclipse the White Star Line's *Oceanic* in length and the Hamburg-American's *Deutschland*, which now holds the ocean record, in speed.

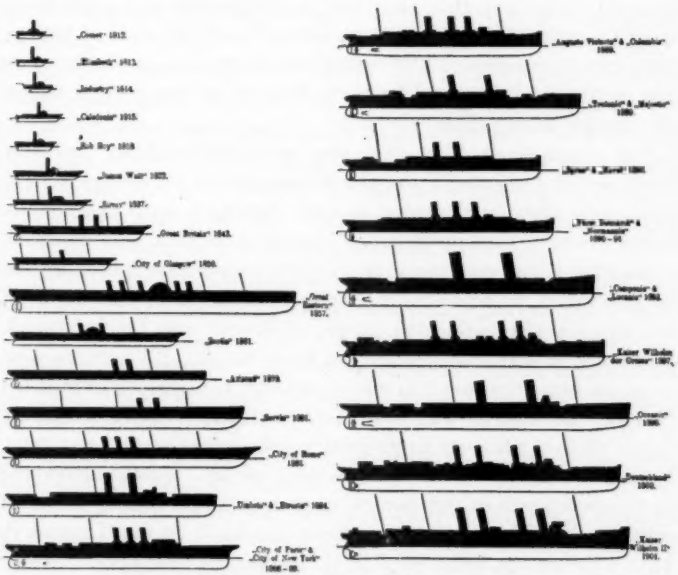
Herr Schlick also presents some interesting notes regarding the development of iron and steel shipbuilding, which we abstract as follows:

The first iron vessels ever built were some canal boats, constructed in England in 1787. Before this time iron could scarcely have been applied to boat construction, since it was only in 1784 that the process of rolling iron plates came into use, and it was in 1786 that the first rolled iron plates were used in boiler construction.

Although from this time on there was a somewhat extensive application of iron to canal-boat construction in Staffordshire, it was not until early in 1822 that a great stride was taken in advance by the construction of the steamboat *Aaron Manby*, which was worked up at Horsley and sent to London for erection. This steamer, under the command of Captain (afterwards Sir Charles) Napier, went direct from London to Havre, and was then put at work upon the Seine, where it rendered satisfactory service for a long time.

Two years later, in 1824, the Shannon Steam Packet Company had an iron steamer built for river service, and this was soon

followed by five others. Progress along these lines then became more rapid, and a number of firms at Liverpool and on the Thames turned out this class of work. The first iron sailing ship was built in 1838 by Jackson & Jordan of Liverpool, and was called the *Ironsides*.



A Chart of Progress in Steamship Construction; 1812-1901.
(Scale: 1 = 4,000.)

About this same time the firm of Tod & McGregor began to play an important role in iron shipbuilding on the Clyde. At that time sailing vessels were built with a gross tonnage of from 200 to 300 tons burden, and steamers had a length of from 130 feet to 200 feet. Among the latter the *Princess Royal* may be mentioned as a vessel noted for its size and speed. It had a length of 195 feet, a breadth of 26 feet, and a depth of 16¾ feet, while its engines were capable of developing 400 horsepower.

In 1843 the *Great Britain* was built. This vessel was of dimen-

sions that had been unheard of up to that time, and marked a great advance in the development of iron shipbuilding. This ship was also the first large screw steamer. She was built at Bristol for the Great Western Steam Packet Co., and had a length of 320 feet, a breadth of 51 feet, and a depth of hold of 32 feet. On a draught of 19 feet, this ship had a displacement of 3,900 tons. It had a capacity for about 1,000 tons of coal, 500 tons of lading, and 300 passengers. The vessel was, however, an unfortunate one, and went ashore in Dundrum Bay on her first voyage, where she lay for a long time.

For some time after this the iron shipbuilding industry remained at a standstill, and the dimensions of the *Great Britain* were only slightly exceeded in rare instances, until the famous *Great Eastern* was produced. This ship, which was so enormous that it has only been equaled in very recent years by the largest types of trans-Atlantic express steamers, was built at Millwall in 1857 after the plans of Brunel and Scott Russell. Although it was commercially a total failure, its construction must nevertheless stand, in many respects, as a sample of modern design. Its length was 680 feet, its breadth 83 feet, and its depth 38 feet, while its registered measurement was 18,915 tons.

About the time of the completion of the *Great Eastern* the first experiments in the use of steel as a shipbuilding material were made. The first steel steamer was built on the Thames in 1857 for Samuda Bros. by J. & G. Rennie.

Curiously enough, the construction of the *Great Eastern* exerted no marked influence upon iron shipbuilding, since the relative size of steamers remained the same both before and after its completion and the later growth was quite gradual. In fact, it was more than a half century later, or in 1899, that the length of the *Great Eastern* was slightly exceeded by the White Star steamship *Oceanic*.

Iron shipbuilding was developed at a much later period in Germany than in England. It is impossible, however, to state with certainty as to when the first was built. Two of the first, possibly the very first, iron vessels to be built in Germany were the *Konigin Maria* and *Prinz Albert*, which were constructed in

1836 from the plans of Prof. Schubert. The first iron seagoing steamship to be built in Germany was constructed at Hamburg in 1838 by Gleichmann & Busse for a Holland firm, and was named the *Willem I.* About this time the same firm built the steamer *Alexandrine*, which later, under the name of *Phœnix*, plied for many years in passenger service between Hamburg and Harburg.

In 1851 Messrs. Fruchtenicht & Brock, two Hamburg engineers, established a small works at Bredow, near Stettin, for the construction of iron vessels, and built in that and the following year *Die Divenow*, which for a time was used in the coal service, and is still in use as a hulk. From this small beginning there has grown that immense establishment known to-day as the "Stettiner Maschinen-bau-Actiengesellschaft Vulcan."

In 1853 the Tischbein dockyards at Rostock turned out two iron vessels for passenger service between that port and St. Petersburg. They were called the *Erbgrossherzog Friedrich Franz* and *Grossfurst Constantin.* The first of these two ships, long known as the *Amsterdam*, is still in regular service between Hamburg and Rotterdam.

In 1854 there followed from the yards of Moller & Holberg, at Stettin, the steamer *Princess Carl.*

On the lower Elbe the first iron river steamer was built at Hamburg in 1855, by the Reiherstieg Shipyard and Machine Works. Two years later this same firm built the first iron sailing ship constructed in Germany, the *Deutschland*, and a short time afterwards built the steamer *Patriot.* The German establishments for the construction of iron ships enjoyed a very rapid development. Their numbers increased from year to year, so that at the present time Germany possesses thirty yards for the construction of iron or steel seagoing vessels. In comparison with England, which now possesses more than two hundred ship yards (though the great majority of them are engaged only in repairs and the construction of small vessels), this is a small number. But, in the matter of their output, the German establishments compare very favorably with England. The extraordinary advances which Germany has made in steel ship con-

struction are principally due to the extensive development of the great German steamship companies during the past ten years.—"Engineering News."

HIGH-SPEED ENGINES.

In a paper on "High-speed Engines," recently read before the Liverpool Engineering Society, Mr. J. Davidson gives the following figures as representing the average present-day practice in the type of engine considered:

I.H.P.	Revolutions per minute.	Piston speed.
50	550	475
100	500	500
150	450	600
200	400	600
300	375	625
400	350	650
600	325	700
1,000	300	700

The difficulty in attaining still higher speeds of revolution lies not only in the great increase of inertia forces, but also in obtaining sufficient area through the ports to admit and release the steam quickly enough. Referring to the fact that excellent double-acting high-speed engines were now obtainable, the author stated that in these wear was avoided by the excellent lubrication afforded, and by the care taken to provide ample area in the bearings. Thus, in an ordinary marine engine the maximum pressure on the crosshead pin is about 1,500 pounds per square inch, the pressure on the guides 60 pounds to 70 pounds per square inch, on the crank pins 500 to 600 pounds per square inch, and on the main bearings 400 pounds per square inch. In a high-speed double-acting engine the corresponding figures would be about as follows: Crosshead pins, 1,000 pounds per square inch; guides, 40 pounds per square inch; crank pin, 400 pounds per square inch, and main bearings, 250 pounds per square inch. All these bearings would, moreover, be supplied

with oil under pressure by means of an oil pump. In illustration of the small amount of wear in the working parts of a modern high-speed engine, Mr. Davidson gave the results of measurements taken on a Willans' central-valve engine of 80 indicated horsepower, after five years' work, the average day's run being 13 hours. In the five years the engine had made over 535 million revolutions. The results of the measurements are given below:

Low-pressure trunks:	
Wear from gland rings; steam gland ring has reduced trunk,	.002 in. in dia.
Air buffer; steam gland ring has reduced trunk,	.015 in. in dia.
Inside wear, due to the valves, could not be measured accurately; but it amounts to about	.002 in.
High-pressure trunks:	
Outside wear due to gland rings,	.003 in.
Inside wear due to valves (approximately),	.002 in.
Cylinders:	
Low-pressure: Wear at the top portion,	.008 in. and .001 in. oval
Low-pressure: Midway, wear,	.007 in. and .0015 in. oval
Low pressure: Bottom of cylinder, wear,	.009 in. and .002 in. oval
High-pressure: Wear at top portion,	.022 in. and .0015 in. oval
High-pressure: Midway, wear,	.0265 in. and .001 in. oval
High-pressure: Bottom of cylinder, wear,	.025 in. and .0015 in. oval
Connecting-rod brasses:	
Worn in the crown,	.02 in.
Cross-head pin:	
Maximum wear on one portion,	.002 in.
Valve-guide pin:	
Wear due to little end of eccentric rod,	.004 in.

Connecting rod:

Small end bush, wear, ... *nil.*

Eccentric rod:

Wear in the bush in the small end is . . .002. in. in dia.

Total wear between eccentric shaft and pin amounts to . . . . . .03 in.

In the strap varies from . . . . . .075 in. to .15 in.

Crankshaft:

The grooves worn at the ends are $\frac{1}{16}$ inch in depth at the governor end, and $\frac{1}{32}$ at the dynamo end.

Journals:

The wear on the journals varies from .001 inch to .002 inch, while that on the eccentrics is *nil.*

That on all four crank pins is .007 inch, all being quite alike, but they may have been as much as .003 inch below standard size originally (this being the maximum deviation allowed from the standard size).

All pins and journals are absolutely round.

Main bearings:

The wear in these varies from nothing at the governor end to .016 at the dynamo end.

Corresponding figures from a Belliss double-acting engine, after a run of three years, were as follows:

Crank-pin main bearing journal, .	$\frac{4}{1000}$ in. to $\frac{6}{1000}$ in.
Low-pressure crank pin, ...	$\frac{10}{1000}$ in.
High-pressure crosshead pin, . . .	$\frac{8}{1000}$ in.
Valve-rod crosshead, ...	$\frac{6}{1000}$ in.
Low-pressure cylinder, ...	$\frac{10}{1000}$ in.
High-pressure crank pin, ...	$\frac{16}{1000}$ in.
Eccentric sheaves, ...	$\frac{10}{1000}$ in.
Low-pressure crosshead pin, . . .	$\frac{8}{1000}$ in.
High-pressure cylinder, ...	$\frac{6}{1000}$ in.
Piston rings, open at joints, . . .	$\frac{1}{16}$ in. full.

The total wear of the shafts and brasses was $\frac{16}{1000}$ inch at the governor end and $\frac{21}{1000}$ inch at the flywheel end. The thickest feeler which could in any way be passed between the solid valve

ring and the valve-chamber bore was found to be $\frac{6}{1000}$ inch, representing, say, $\frac{4}{1000}$ inch wear from the original dimension. —London "Engineering."

USE OF VARIOUS VAPORS IN MARINE ENGINES.

The author considers, from a thermodynamical point of view, the use of vapors other than steam as the motive power of marine engines. Among other advantages claimed for the use of petroleum vapor, it is stated that the heating value of the fuel is used to greater effect, owing to the fact that the formation of petroleum vapors requires a considerably smaller quantity of heat than is the case with steam. The author indicates the fallacy of such reasoning, and shows that if the original temperature of the liquids be 20 degrees centigrade, the amount of heat necessary for the production of a cubic meter of steam at 6 atmospheres pressure is 2,082 calories, whilst in the case of petroleum ordinarily used, which is composed of the hydro-carbons $C_7 H_{16}$ and $C_8 H_{18}$, and has a mean molecular weight of 108, 2,460 calories are required; for alcohol the corresponding number of calories is 2,390. The real advantages offered by the employment of such vapors, which make them eminently fitted for the engines of pleasure boats, are cleanliness of working, the use for heating purposes of part of the vapor produced in the boiler, and, finally, the high-conducting power of the liquids and the consequent possibility of using small boilers.

Great efficiency would be obtained by making use of a liquid of low molecular weight and relatively low heat vaporization. Such a liquid presents itself in liquefied ammonia, but its use in an engine working with a condenser would be impracticable.

Petroleum and similar liquids also find application in lifeboats, in submarine boats, both to propel them when at the surface and to charge the accumulators for the dynamos used to drive the boat when under water; in sailing yachts, for auxiliary motors, and for other such purposes.

The author considers also those cases in which the steam, after coming from the cylinder, is employed to evaporate a second

liquid, the vapor of which is also made use of for driving the engine. When ether is taken as this second liquid, the author shows that the theoretical amount of work obtainable from a given quantity of steam may be increased by 10.7 per cent. without any increase in the amount of heat consumed, the losses unavoidable in practice would alter this number but slightly.

Ether vapor owes its especial value as a means of converting heat into work to a peculiar property, the possession of which is indicated by theory and confirmed by practice—namely, that when it expands and does work, heat must be withdrawn from it in order that it may remain saturated; from this it follows that if the amount of heat passing through the walls of the cylinder be kept within certain limits, no deposition of liquid occurs in the cylinder, a great advantage over steam being thus obtained. Further, for the same yield of work, the temperature of working, and hence also the loss of heat, is lower for ether than for water. These considerations explain the success obtained some years ago by Mr. DeSusini, who passed steam at 2.5 atmospheres pressure into a surface condenser, the tubes of which were filled with ether. The ether vapor thus obtained, having an initial pressure of ten atmospheres, was used to drive an engine with specially constructed stuffing boxes, etc., after which it was condensed and returned to the tubes of the surface condenser. Direct heating of an ether boiler would be attended with danger owing to the great difficulty of regulating the heating.—Inst. C. E., Foreign Abstracts.

GERMANY AND SUBMARINE BOATS.

The question as to the utility of submarine boats for naval purposes does not appear to have yet received serious consideration in Germany, and for that reason an article which was recently published in the "Allgemeine Marine Correspondenz," discussing whether the Fatherland has any need for vessels of this type at the present time, is worthy of mention at this juncture as representing a Teutonic view of the subject. After characterizing the claims made by some papers regarding the performances of submarine boats as far exceeding the actual limits,

the German journal points out that France already possesses eight submarine boats, and has six in course of construction, with more to follow. The United States Government owns two completed and has six building; England is constructing five of the same type as the American vessels; Russia is having a large boat built in Paris and a small one in St. Petersburg; whilst Italy is still making experiments with the *Delfino*, which was constructed at Spezzia. In addition to these, Spain possesses the *Peral*, which has been discarded; Greece has two completely unserviceable old Nordenfelt submarine boats; and Turkey has two similar vessels, which are not much better, and are of the same origin. As only the *Morse* and the *Narval* of the old French submarine boats come into consideration, the following vessels may be available during the course of the present year: Twelve French, eight American, five English, two Russian, and one Italian, being a total of 28 boats. The remainder are antiquated, and do not count.

As to the position of Germany, the journal states that in view of the high development of shipbuilding in that country it would not be difficult for native firms to produce submarine boats, and that when the time arrives it would be possible with the present capacity of Teutonic yards to have dozens of these vessels available on the coasts within a few months. This time is, however, not so near as many persons believe, since all submarine boats without exception possess two great defects which place in question their applicability as modern weapons of war, namely, their slight longitudinal stability and their limited range of view. When a submarine boat is completely submerged it is in unstable equilibrium, and is immediately brought out of its horizontal position if weights are displaced internally. The bow sinks if one of the crew goes from the center forwards, and rises to the surface when a torpedo is discharged from the bow tube. Down to the present time, the German journal proceeds, the sole possibility of obtaining a certain longitudinal stability lies in the conversion of the unstable equilibrium of the completely submerged boat into stable equilibrium, as the vessel would be given a certain lifting power, or, in other words, the boat would be trans-

formed from a submerged condition to that of being barely immersed. The steering tower can only afford an extremely limited outlook in a rough sea, because it only rises slightly above the surface of the water, and although the periscope has been considerably improved, it does not yet meet the practical requirements, especially in a troubled sea, whilst it altogether fails at night.—London "Engineering."

EXPERIMENTS WITH LIQUID FUEL.

Under the head of "Boilers" in the statement of work issued by the Admiralty it is stated that experiments in connection with the use of liquid fuel are being carried out in one of the new boilers of the *Blonde*, erected on shore at Devonport, and in the torpedo boat *Surly*, at Portsmouth. In the latter vessel the system of assisting the combustion of coal by oil fuel is also being tried. Plans are also being considered of fittings for making further trials of the combination of coal and oil in a Belleville boiler, and also in his Majesty's ships *Hannibal*, *Mars* and *Arrogant* in the Channel Squadron. In consequence of the interim report of the Boiler Committee, it was decided to replace any of the Belleville boilers that were not too advanced by the types of water-tube boilers recommended by the above committee. Consequently the battleship *Queen* and the first-class cruiser *Cornwall* are to be fitted with the Babcock and Wilcox type of water-tube boiler, and the first-class cruiser *Berwick* with the Niclausse type, instead of the Belleville types originally ordered.—"Naval and Military Record."

THE EVOLUTION OF THE DESTROYER.

When destroyers were first designed it was not contemplated that they would be frequently used otherwise than as working from the fixed base. Experience, however, has shown that vessels with greater sea-keeping power are required for service with fleets, and accordingly the Board have decided to materially strengthen the type of future destroyers, and to create a new

class altogether, to which the name *Scout* has been given. The Admiralty will not initiate a design for this new class, but the private shipbuilders of the country will be invited to submit designs to fulfil certain stated conditions. Moreover, a committee has been appointed to advise the Admiralty in respect of the strengthening of some of the existing vessels. The Board have often been urged to build large numbers of destroyers at the same time, but this advice I do not believe to be sound. In the first place, the destroyer is a type which is still in process of rapid evolution, in the second, it must by its nature be a short-lived type of vessel, and to build large numbers in the same year would inevitably result in large numbers becoming obsolete and worn out at the same moment. The true policy seems to be steady, as opposed to spasmodic construction. Henceforward Sheerness will be gradually more and more used as the special dockyard at which destroyers will be repaired.—"Naval and Military Record."

ELECTRICAL OPERATION OF TOOLS.

Abstract of a Lecture by Robert T. Lozier before the New York Electrical Society.

At a recent meeting of the New York Electrical Society a paper was read upon "The Electrical Operation of Modern Tools and Machinery" by Robert T. Lozier, district manager of the Bullock Electric Manufacturing Company, 220 Broadway, New York. The extracts from the lecture which follow bear directly upon the use of electric power transmission in machine shops.

Perhaps the most interesting feature of the subject is comparing the electrical operation of tools and machinery, either by a subdivision of the power, or individual application, with the old method of transmitting power from the main engine entirely by belts and shafting. At the present time the new shops that are driven entirely by belt transmission are in the minority, and generally operate under conditions of such peculiar nature as to make the shaft and belt system particularly desirable.

At the meeting of the American Society of Mechanical Engineers in December, 1896, Prof. C. H. Benjamin read an exhaustive paper on the losses in the distribution of power in machine shops, giving the results of very thorough tests in sixteen different establishments. The accumulated data are briefly summarized in the accompanying table, which shows

	Length of line shaft.	Total H.P.	H.P. to drive shaft, &c.	Per cent.	At what capacity.
Wire drawing and polishing...	1,130	400	157	39	One-half.
Stamping and polishing.....	580	74	57	77	One-third.
Boiler and machine tools.....	530	38	25	65	Two-thirds.
Bridge machinery.....	1,460	59	48	81	Nearly full.
Heavy machine tools.....	1,120	112	64	57	Full.
Heavy machine tools.....	1,065	168	91	54	Full.
Light machine tools	748	40	20	51	Full.
Manufacture of small tools	500	74	40	54	Full.
Manufacture of small tools	990	47	24½	51	Full.
Sewing machines and bicycles.	2,490	190	108	57	Full.
Sewing machines	1,472	107	75	70	Full.
Screw machinery	1,800	241	114	47	Full.
Steel wood screws.....	674	117	17	14.5	One-quarter.
Manufacture of steel nails.....	988	91	45	50	Full.
Planing mills	165	39	28	73	Full.
Light machine tools.....	275	8	4	50	One-half.

Average loss, 55 to 65 per cent.

that the average loss involved in the transmission of power represents from 55 per cent. to 65 per cent. of the total power generated. Say it is 50 per cent. of the total power, then it will represent 100 per cent. of the effective, or useful, power. If we have a plant of 100 H.P., and it requires 50 H.P. to operate the tools, and 50 H.P. to get the power to the tools, we are losing 100 per cent. of the effective, or useful, power. And we must not forget that this loss is fixed and is not reduced as the load diminishes, so that if the useful power should drop to 25 H.P., this waste power would become 200 per cent. of the effective power.

Professor Benjamin, in analyzing the distribution of power in the shop, says: "Stating the case roughly for the ordinary

machine shop, every 100 indicated H.P. of the engine may be distributed thus:

Friction of engine	10 H.P. or 10 per cent.
To drive shafting	15 H.P. or 15 per cent.
Belts and pulleys	15 H.P. or 15 per cent.
Empty machines	15 H.P. or 15 per cent.
Cutting material	45 H.P. or 45 per cent.
	100 H.P.

"Even this efficiency would probably be realized only when all the machines were working at their full capacity."

He thus found the average loss in getting the power to the tool to be 55 per cent. of the total, or 122 per cent. of the effective, while in the test on the group system, operated by motors, taken on the basis of 100 feet of line shafts, he found—

Motor and shaft	12 H.P. or 30 per cent.
Machines	28 H.P. or 70 per cent.
	40 H.P.

It will be noted from the foregoing that driving and transmitting force is but 43 per cent. of the effective, instead of 122 per cent. in the case of all belt driven. Professor Benjamin does not state whether he has included in the motor unit its proportionate share of line loss, 5 per cent., and generator loss, 8 per cent. But these latter are more than offset by the circumstance of the tools being shut down when all loss is stopped.

Mr. Gano S. Dunn, in a paper presented before the American Institute of Electrical Engineers, on April 26th, 1899, put the problem as to whether it was advisable to use 100 feet of shafting driven by one motor, or three groups of $33\frac{1}{3}$ feet each, driven by three smaller motors, as follows: "Taking a duty of 1 H.P. upon the shaft for every five feet of length, corresponding to like machine-shop practice, and taking a coefficient of friction of 5 per cent., and a speed of 200 revolutions, transmitting 200 H.P., with the belts pulling horizontally in opposite directions, we find the per cent. of saving in using three small motors, instead of one, is 2 per cent."

This is getting the question of economy down pretty fine. In this statement Mr. Dunn puts in the hands of the engineer means

of determining how far the question of subdivision of the prime movers can be carried, purely from the standpoint of efficiency.

Of course, if a separate motor is applied to each tool, the loss in transmission becomes almost negligible, in spite of the theoretical losses that are sometimes attributed to the slow-speed motors that may be used in that system. In large plants in which the individual motor is freely applied it is found that the average load of the generating plant is but $\frac{1}{6}$, or $16\frac{2}{3}$ per cent. of the total connected load, including the electric lighting, cranes and trams; that is to say, if we have a plant, the motors and lights of which aggregate 1,000 H.P., it is not unreasonable to expect that the demand upon the generating plant will run about 166 H.P., and that this demand will not exceed the maximum of 250 H.P. for a considerable length of time; so it will be seen that a plant with such a large connected load can turn out its considerable product with a remarkably small expenditure of power.

Now what does this question of economy in power represent in dollars and cents to the producer? Prof. Chas. E. Emery, in his paper of March 23d, '93, before the American Institute of Electrical Engineers, tells us that the costs of producing a mechanical H.P. are as follows:

With coal at $3.00 per ton for simple high-speed non-condensing engines, for 10 hours a day for one year (about 500 H.P. generated), $36.17 per H.P.; with special low-speed triple-compound engines, $24.19 per H.P.

From these costs it is not difficult to determine what ratio the cost of power bears to the product of the shop which it drives. From empirical data I am able to state that the average ratios run pretty close to the following:

COMPLETE BELTING TRANSMISSION.

With the cost of steam power at $36.17, 2 per cent. of product.
With the cost of steam power at $24.19, $1\frac{3}{8}$ per cent. of product.

SUBDIVIDED MOTORS.

With cost of steam power at $36.17, 1 per cent. of product.
With cost of steam power at $24.19, 0.8 per cent. of product.

INDIVIDUAL MOTOR DRIVES.

Here the amount of power involved is so small as to increase the cost per unit, but I have known it to be less than 4 per cent. of product.

Assume a locomotive shop, a large cloth-printing concern or any other establishment in which a large amount of power is used in running its machinery to produce an output which we say amounts to one million dollars a year, and, if we assumed that they use the very best methods of producing their power, we find the cost of that power per year, with the different methods above outlined, to be as follows:

Method of drive.	Cost of power.	Yearly saving.
All belts and shafting, . .	$17,000	———
Subdivided motors, . .	8,500	$8,500
Individual motors, . .	4,000	13,000

So that a subdivided motor system saves enough over the old method of belt and shafting to pay 10 per cent. yearly on a plant that would cost $85,000, and the individual motor application could support, at that rate, a $130,000 plant. Of course, the latter need not be entirely composed of individual motors, but groups of small machines can be driven by one motor whenever that method seems best.

From the foregoing figures we can tell, with reasonable closeness, what this subject of economy in power transmission means, and how far it will go toward representing the interest and depreciation upon the plant that it is necessary to purchase in order to accomplish such savings. The figures are given from a broad standpoint; they have been gathered from actual plants now in operation and may be taken to fairly represent general conditions. So much for the question of economy.

In every line of the civilized world people are endeavoring to increase the sphere of action by increasing the quickness of operation. We use the telephone because it is quicker; trolleys because they are quicker; automobiles because they are quicker; and one of the greatest factors in determining the speed of the trolley and the automobile is the quickness of their control.

The question is asked on every hand, what is the quickest method we can apply? Not what is the cheapest in first cost, nor in which the smaller economies are apparent.

Let us, therefore, leave the question of what we are going to save in power transmission and other considerations of relatively minor importance and go at once to those matters of increased output and entire flexibility in the arrangement of the shop equipment.

It is true that the individual motor, properly controlled, can increase the product of an establishment. I have it, on good authority, from several sources where such equipments are used, that the outputs have been increased from 8 per cent. to 25 per cent. with the same equipment and pay roll, due directly to the use of these motors, which many times are used in conjunction with a group-drive system.

If it is true that with increased speed facilities we can increase the output, and we limit that output, in the case of the individual motor, to say 10 per cent.—and that is low enough to cover the increase in most any kind of a well-arranged plant—then let us consider the case that we took as a basis to determine the relative cost of transmitting the power—an establishment producing a million-dollar product yearly. If we can increase this product by 10 per cent., we have $100,000 more with the same shop equipment and the same expenditure for fixed charges and pay roll. Allow for raw material, say $25,000, and we can credit the motor equipment with $75,000 a year.

This will probably more than pay for the entire equipment of individual motors in the first year, and in addition, the purchaser has the saving in power transmission, a free and clear head room permitting of the use of over-head cranes, which, in these days of rapidly moving machinery, we must have to handle the product. He is able to reorganize and rearrange his shop at any time, to remove old tools and make room for new.

To indicate the success of the individual motor in fulfilling all the demands put upon it, some of which have been almost abnormal, I will refer to the equipment of the shops of the Fore River Engine Company, of Quincy Point, Mass., a large estab-

lishment designed in accordance with the latest and best engineering practices and one in which the individual-motor drive is giving a practical demonstration of its complete success.

This plant has a connected load, consisting of motors, arc and incandescent lights, of nearly 3,000 H.P. and its average load is about 260 H.P. This latter item may be increased as more work is put upon the tools. The load at present is distributed among 112 motors, half of which are of 5 H.P. or under. To get an idea of the service put upon an individual motor, I have here to-night some data on some very heavy turning work, and have samples of the chips. The tool was a 60-inch lathe, running with all back gears in head of lathe, the motor of 6½ H.P. capacity, operating at full line voltage. Results were as follows:

Machining 20-inch steel shaft 32 feet long, weighing nearly 24 tons, taking two chips, one tool following the other. Feed was ⅜ inch. Cutting speed, 18 feet per minute. Line voltage, 235. Ampères, no load (rotating steel shaft only), 36; 12 H.P., or 66 per cent. of motor load. Ampères with average load, 45; 15 H.P., or 250 per cent. of motor load. Ampères with maximum load, 80; 26 H.P., or 433 per cent. of motor load.

Owing to the excessive overloads, it was necessary to change one set of brushes. It was, however, an emergency job; the motor was kept at its work, and Mr. F. O. Wellington, the general manager of the company, stated he believed it to be the quickest job ever done with so large a piece of material. The motor did not heat excessively, although it stood at over 300 per cent. overload for periods of at least half a minute.

Mr. Lozier went exhaustively into the various methods of speed control, closing by saying that if individual motors were to be used it was of great importance that they be large enough, advocating a margin of at least 25 per cent. over what was supposed to be a generous estimate.—"Machinery."

PROTECTIVE COATINGS FOR THE IMMERSED PORTIONS OF IRON VESSELS.

The advent of iron ships has been accompanied with a difficulty which has not yet been met satisfactorily, namely, that of

a suitable protective coating of the immersed parts to protect them from corrosion and the attachment of marine plants and animals. The latter is the most troublesome, and especially in tropical waters the rapid accumulation of marine growths of this nature in the course of a few months fouls the bottom of iron ships to such an extent that the speed is reduced to one-half or even more. This, of course, materially reduces the efficiency of a vessel—especially of a naval vessel—and necessitates frequent docking for scraping and cleansing.

The old plan generally employed with wooden vessels was to sheath them with copper sheathing. In the case of iron vessels, however, this cannot be done without first applying wooden sheathing to which the copper can be attached, and this is a somewhat expensive operation, which, on this account, is only occasionally resorted to. Nevertheless, unless some efficient substitute for copper sheathing is devised in the near future, this expensive method will have to be adopted.

Attempts have been made to coat the iron hulls of ships with copper electrically by a process of electric plating on a huge scale, but those appear to be unsuccessful. Meantime recourse has been had to the application of various paints and similar protective coatings, none of which, thus far, have proved entirely satisfactory.

The "Chemiker Zeitung" has an instructive article on this subject, from which the following information is derived: The author enumerates the following indispensable conditions for a protective coating for iron ships to realize the requirements of service: (1) The compositions should protect the ship's hull from corrosion; (2) they should form a smooth surface, so as to decrease the friction, and (3) they should dry quickly, so that the cleansing of the submarine parts and the application of a double coating can be done in a single day. In the case of new steel vessels the black scale with plates must first be removed by the use of acid pickle before applying the coating, which otherwise will drop away with the scale and expose the exposed metal to rusting.

The author describes several paint compositions that have been

used for this purpose, and gives the preference to that proposed by Rahtjen. This process consists in employing as the vehicle a solution of shellac in spirit, to which is added some iron oxide and a small proportion of linseed oil to give it elasticity. This first or priming coat is intended to serve for insulating the iron hull, and is followed by a second one composed of the same materials, with the addition of arsenic and quicksilver. The Rahtjen compositions are highly commended for their permanency, as the salt of the sea water has but little action on the shellac, which constitutes the vehicle of the paints. The efficiency of the second coating as a preventive of marine growths is ascribed to the formation of mercuric chloride by the slow action of the sea water on the quicksilver contained in the composition, and which acts as a poison towards the marine organisms. These paints have the further advantage that they dry quickly, so that several coats may be laid on in a single day.

The defects of the Rahtjen paints are, that only a small quantity of mercury can be incorporated in the paint, as otherwise the shellac would be affected, and that the effectiveness of the paint decreases with time because of the slight solubility of the shellac.

Of the mineral poisons incorporated in these compositions, copper and mercury have been found most efficacious. Copper would be preferable on account of the cheapness, but has the objection that when the insulating or priming coat has become defective, its presence in considerable quantities in proximity to the iron hull is apt to cause rapid corrosion of the iron by galvanic action.

The author of the article above referred to gives also some instructive information as to the manner in which the efficiency of such protective compositions is called into action. Thus he explains: the purpose of the poisons in the paint is to kill the germs of the crustaceous animals, which only swim about freely during the first stages of their development, and, in seeking a permanent place of growth, attach themselves to the vessel's hull. While the ship is moving through the water the paint layer is being continually affected by friction, so that the sea-

water can enter into chemical action with the poisons of the paint, whereby there results the production of an antiseptic (germicide) compound on the surface that destroys the organisms which come in contact with it, and so long as the ship's motion is continued, fresh portions of the paint film are successively exposed with the same result. In time the antiseptic action of the paint film ceases by the exhaustion of the poisonous material, when its virtue as a preventive of marine growths ceases, though the insulating coating may still protect the hull from corrosion.

Again, when the hull of the vessel is at rest, as when in harbor, the continuous formation on the surface of the paint layer of an antiseptic substance is arrested, being rapidly exhausted by the vast amount of animal life coming in contact with it, and not being renewed by frictional contact with the water, as when the ship is in motion. This is the explanation of the fact that a vessel in port (particularly in tropical waters) fouls much more rapidly than when at sea. It is observed, however, that the antiseptic agents which have thus become exhausted after a few weeks' detention of the vessel in court again become effective after putting to sea, when the exhausted particles of the paint skin are removed by friction, exposing a new poison-saturated surface.

The whole subject of the proper protection of the hulls of iron vessels from rusting and marine growths is in a sort of transition stage, very much like that of finding an efficient substitute for wood on warships, for, notwithstanding the many remedial agents that have been proposed, none of them has fully met all the requirements, and the problem still awaits its solution.—W.—"Journal of the Franklin Institute."

CASE HARDENING WROUGHT IRON AND MACHINE STEEL.

By E. R. Markham.

Hardening the surfaces of articles made of wrought iron and machinery steel is generally termed case hardening. Most machine shops have some means whereby they can harden screws, nuts, and similar small articles. Where there are only a limited

number of pieces to harden it is customary to heat the work in the blacksmith forge, in a gas jet, or in any place where a red heat can be given the piece. When hot, sprinkle a little granulated cyanide of potassium, or a mixture of prussiate of potash, sal ammoniac and salt; reheat to a red and plunge in clear, cold water. When there are large quantities of work to harden this is an expensive as well as a very unsatisfactory way.

To case harden properly we must understand the material of which the article is made and the purpose for which it is to be used, whether it is simply to resist wear or friction, will be obliged to resist sharp or heavy blows, a bending or twisting strain, or do we wish merely to produce surface colors?

We will first consider the case hardening of work that simply needs a hard surface, with nothing else to be taken into consideration. Pack the articles in an iron box made for this purpose, using a mixture of equal parts by measure of granulated raw bone and granulated charcoal mixed thoroughly together. Cover the bottom of the hardening box to a depth of 1½ inches with the mixture, pack a row of work on this, being sure that the articles do not come within ¼ to ½ inch of each other, or within 1 inch of the walls of the box. Cover this with the packing to a depth of ½ inch, tamp down, put on another layer, and so continue until the box is filled to within 1 inch of the top, filling the remaining space with refuse packing material left from previous hardenings, if we have it; if not, fill with charcoal or our packing material. Tamp well, put on the cover and lute with fire clay to prevent as much as possible the escape of the gases.

If the articles are so large that they would not cool below a red heat before reaching the bottom of the bath, they should be wired before putting in the hardening box. We should use iron binding wire sufficiently strong to hold the work when it is worked around in the bath. If the articles are too heavy for wiring, we must devise some other way of holding, either tongs or grappling hooks. If the pieces are small they can be dumped directly from the box into the tank, sifting the work out of the box somewhat slowly, so that the articles will not go into the bath in a body. If the tank is large enough it is a good plan to

have wires across from side to side, about four inches apart in the horizontal rows. Have the rows three or four inches apart, and do not put the wires underneath each other, but in such a manner that the work will strike the different wires as it passes to the bottom of the tank. In striking these wires the work will be separated, and any packing material adhering to it will be loosened by the jar; the work will also be turned over, thus presenting all sides to the cold water as it passes through.

These wires can easily be arranged by taking two pieces of sheet metal a little shorter than the inside length of the tank, drilling holes in them as described in the arrangement of the wires, and the wires can be passed through these holes and riveted, thus making a permanent fixture that can be placed in the tank and taken out at will. The distance between the wires can be varied to accommodate the particular kind of work we are to do; they must be far enough apart so that the work cannot lodge on them. Any one troubled by the case hardening being soft in spots will find a remedy in this simple device: Do not have any wires within 8 or 10 inches of bottom of tank. Have a coarse screen or a piece of sheet metal drilled full of holes somewhat smaller than the pieces we are to harden; block it up about 2 inches from the bottom to allow a free circulation of water underneath it. This also allows the water to pass through it around the work, and the packing material will pass through it, leaving the water a better chance to get at the work. The water inlet should be at the bottom of the tank, and we should have an outlet about two inches from the top to allow the surface water to escape. The cold water coming up from the inlet at the bottom should be turned on before we dump the work, allowing it to run until the work is cold.

In heating the work any form of furnace will do that will give the required heat and maintain it evenly for a sufficient length of time. The covers of the boxes should have several $\frac{1}{4}$-inch holes drilled near the center. After putting the cover in place, put pieces of $\frac{3}{16}$-inch wire through these down to the bottom of the box, allowing them to stick up an inch above the cover, to enable us to get hold of them with the tongs. When it is

thought that the work has been in the fire long enough to heat through, draw one of the wires with a long pair of tongs or take an ordinary pair and put some pieces of gas pipe on the legs. If the wires are red the entire length we time from them, and, if not, we wait a few minutes and draw another, and so on until we draw one red the entire length. I consider this the proper method to employ in timing all work in a fire, whether it is to be annealed or case hardened, charging for hardening by the Harveyizing method or when we are pack hardening tool steel. If we time our work from the time we put it in the fire we are uncertain as to the results if the fire is hotter one day than it is another. Some days our fire acts dead, another day lively, so our pot is longer in heating at one time than another; but if we time from the period when our work commences to take carbon, we will have results as nearly uniform as it is possible to get, provided we have a uniform heat, which can be gauged quite closely by the eye. Better results can be obtained by use of the pyrometer, although for ordinary work this is not necessary.

After running the proper length of time in the fire, which varies according to the nature of the steel and the purpose for which it is intended (small articles, $\frac{1}{4}$ inch or less, which do not require anything but a hard surface, should be run from one to two hours after they are red hot), dump into water. If it is desirable to have them colored somewhat, hold the pot about a foot or eighteen inches above the tank, allowing them to pass this distance through the air before striking the water. If we are hardening small screws with slots for screwdriver, and are hardening simply to keep the screwdriver from tearing the slot, we can use expended bone; that is, bone that has been used once before. It will make the work hard enough for all practical purposes, yet not hard enough to break. If we wish to harden deeper we must run longer. To harden $\frac{1}{16}$-inch deep, it is necessary to run about five hours after the work is red. By running sixteen to twenty hours we can harden to a depth of $\frac{1}{4}$ inch. In the case of small articles it is best to use a bone not coarser than what is known as No. 2 granulated raw bone. When we are to run for a long period of time in the oven we should use a coarser grade. The charcoal used in the mixture

should, if possible, be of the same sized granules as the bone. The commercial article is much superior to anything we can pound and sift, so that it is policy to buy it. The first cost may seem a little stiff, but if account is taken of the time it takes to grind and sift, we will find the article we buy the cheaper.

There are many special preparations used in case hardening, some of which are excellent for special work, while some are good for all kinds of work. When we wish to harden deep in a short space of time it is advisable to use bone black in place of granulated raw bone. Bone black—or animal charcoal, as it is commercially called—is prepared by burning bones in a special furnace. It comes in the form of a powder; it leaves a finer grain in the work hardened, and will make it stronger than if hardened with raw bone.

Another form of bone which gives excellent results is called hydrocarbonated bone, a form of bone black treated with oil, so that it gives off its carbon more readily than either form mentioned before. It is not generally used, but for very nice work it is very satisfactory.

If we wish to give a nice color to our work it is necessary first to polish it and to be sure that it is clean when packed in the hardening box. Use the following mixture when packing: 10 parts No. 1 granulated raw bone, 2 parts bone black, 1 part granulated charred leather; mix very thoroughly before using. The results will be much more gratifying if we pipe into our bath, placing the end or outlet near the bottom. By means of an air pump of some description force a jet of air into the water in such a manner that it will be distributed throughout the whole tank, in order that each piece of work may come in contact with the air as it passes through the water. When articles are hardened by the first process mentioned, heating in fire and treating with cyanide of potassium, very nice colors can be obtained by taking a piece of pipe, putting it in the bath and blowing through it, passing our work through the air in the water when we dip it.

When the articles are thin and must be very hard, yet tough, it is best to use a bath of raw linseed oil. If this bath is used it is advisable to attach a piece of iron binding wire to each piece when we pack the work, allowing the wires to hang over the

sides of the box. When we remove the box from the fire the articles can be removed from the box and immersed in the oil by means of the wires. They should be worked around well in the bath until the red has disappeared, but in such a manner that broad sides are not moved against the cold oil, or the article will be liable to spring. In the case of a long, slender piece work it up and down, moving sideways each time, so as to come in contact with cool oil and get away from the vapors that are formed, as they hold the oil from the work, thereby preventing hardening.

In many shops it is customary to make snap gauges of machine steel. They are much easier made, the cost of material is less, and if hardened properly they will wear well. It is best in cases of this kind to use open-hearth steel rather than Bessemer, as the latter runs so uneven. When charging in the furnace, some pieces will harden to a depth of $\frac{1}{16}$ inch if run four or five hours, while another piece 1 inch thick will harden entirely through in an hour. Open-hearth steel runs very uniformly when hardening, according to my experience. The best results will be obtained if we use granulated charred leather instead of bone. When packing mix with an equal amount of granulated charcoal, run five or six hours if the gauge is $\frac{1}{4}$ inch thick or over. Run at a very low heat and dip in the oil bath; it will be found to be very hard, and probably straight.

In hardening small pieces it is advisable to use a small box, as it takes some time to heat a large box through; the pieces on the outside will be much harder than those nearer the center. After hardening we should dry the bone used in packing. It is not only useful for packing articles we do not wish very hard, but is excellent to use when annealing cast iron that will not soften when packed in clear charcoal.—"American Machinist."

HARDENING EXTRA-LONG STAY-BOLT TAPS.

E. R. Markham.

In hardening very long pieces of steel that cannot be straightened if they spring, and that will also not allow of grinding, great

care must be exercised, not only in the hardening, but also in the various operations of machining the metal to the desired shape. Furthermore, it is not advisable to use the highest carbon steel when a tool such as a tap or a reamer is to be made, if it is to be hardened by the method to be described below.

A stay-bolt tap 44 inches in length is, however, not a difficult job, provided we go at it rightly. The stock to be used in making such taps should be at least one-eighth of an inch larger in diameter than the finished tap, in order that its decarbonized surface, caused by the action of the oxygen in the air on the surface carbon of the steel during its various treatments in the steel mill, may be thoroughly removed in machining. After removing this outer surface of the stock by turning down in the lathe to within $\frac{1}{16}$ inch of size, the steel should be packed in an iron box with powdered charcoal and subjected to an annealing heat, care being taken to make certain that the box is heated evenly and thoroughly to the proper temperature, which may be determined by means of test wires to be described later. The proper heat for the annealing of pieces from which it is desired to remove strains is a bright red. This is higher than a hardening heat, but it will remove any strains, due to unequal contraction, that may be in the steel incident to the operation in the steel mill or forge. The slower the steel cools, the better. The grain of the steel will become refined when it is heated to a low red for hardening.

If any of the pieces when taken from the annealing box are sprung, do not attempt to straighten them *cold;* it is best not to straighten at all. Turn the spring out; but if they are sprung too much to allow of this, heat them to a bright red, or forging heat, and straighten, and then anneal them afterward as before. Much care should be taken in finish-turning, threading, or milling, that the tools are very sharp, and ground correctly, as it is an easy matter to pene a piece of steel with a dull cutting tool, this being especially true in regard to a milling-machine cutter. Also a piece of work may not only be sprung by a dull mill, but it can be stretched enough to destroy the accuracy of a tap. When the taps are machined and ready to harden, it is well that

they be tested between centers to see that they are true, as it is not charitable to blame the hardener for mistakes of the tool maker.

The only shape of hardening box that I should advise for use with this class of work would be one high enough to stand the pieces in upright, having at least one inch clearance space at the top and the bottom. The boxes should not be made too large; one capable of holding four taps and allowing plenty of space for packing material around them would give better results than one capable of holding more, as the heat would then be applied more uniformly. The dimensions for such a box would be 47 inches by 6 by 6 inches. The ends could be left out of the pattern and a bottom fitted into the box after the casting is made. The cover should be a little smaller than the inside of the top of the box, so it will not stick when the iron of the box becomes warped by use, and there should be some means provided for fastening it on the box securely if the furnace is not high enough to allow the box to stand upright, as not many ovens are built that would accommodate this height of box, and few furnaces would give an even heat the whole length of the box if they could hold it. The results, so far as straightness is concerned, would be surer if the boxes were heated on end; but if the packing material is tamped in solidly around the taps, good results can be obtained if boxes are laid on side by making sure they are not within one-half inch of each other, or within one inch of the walls of the box at any point.

The packing material to be used consists of granulated charcoal and granulated charred leather, a sufficient quantity of which should be mixed up in equal parts of each to entirely fill the hardening box around the taps. There should be several $\frac{1}{4}$-inch holes drilled through center of cover, through which $\frac{3}{16}$-inch wires long enough to run to the bottom of box are to be inserted before heating up the box. When the box is according to judgment heated through, it may be tested by drawing out one of these wires; if the wire is red hot throughout its entire length, time from then; but if not, wait a few minutes and then test by drawing another, and so on until finally one is drawn that is of the required evenly-heated condition. The work should then

be run at a low red heat for two hours for a 2-inch tap, and smaller ones for a correspondingly shorter time. At the expiration of this time the box should be removed from the furnace, stood on end with the cover up, and the cover then removed. Then with a suitable pair of tongs the taps should be drawn out carefully through the packing material to avoid springing, and immersed in a cooling bath of raw linseed oil, which should be kept cooled by circulation through a coil of pipe immersed in cold water. The pieces should be plunged straight down into the center of the bath, and worked up and down steadily until the red has disappeared, when they can be moved to the edge of the tank, by still being worked straight up and down. Another person could in the meantime take the second tap from the box and manipulate in the same manner, so that in this way two men can handle the four taps all right, as the packing material will keep the others hot until their turns come.

It is quite necessary that the contents of the cooling bath should be agitated in such a manner that the oil will flow from the edges of the tank towards the center. This forces any vapor formed by contact of the heated steel and oil away from the work, doing away with the tendency to form soft spots on the work. The tank for the bath should be at least 60 inches deep and from 42 to 36 inches square. It should be set in a large tank of water, and one or two pumps of suitable size should be connected with the tank to draw the oil from near the top of the bath, force it through coils of pipe immersed in the water tank, and then back into the oil tank about 18 inches below the surface. If these two pumps are connected to the tank opposite each other the oil should be agitated sufficiently by these two streams thus forced toward each other. The oil in tank should never be allowed to get as low as the suction pipe, or air will become mixed with the oil in the jet.

They should be left in the bath until they are cold, after which the temper must be drawn. The most satisfactory method of drawing the temper on such work is in a kettle of hot oil, gauging the heat by means of a thermometer or pyrometer. The dish that it is heated in should be long enough to allow the taps to lie lengthwise, and blocking should be put in to hold them up 2

or 3 inches from the bottom by supporting them every 6 or 8 inches to avoid any tendency in them to spring. The dish should be placed over a gas pipe to which are attached several burners, which should be located 4 or 5 inches apart. The thermometer should be placed in the oil standing nearly vertical, but should not go deeper down than the taps. The oil in the dish should be kept in motion by gentle stirring, but care should be taken not to "slop it over," as it might take fire.

The amount to which the temper must be drawn will depend on the amount of heat the pieces have received and the nature of the stock they are made of; but if the directions given are closely followed 500 degrees Fahrenheit will probably be found about right. As stated before, the oil used in the bath should be raw linseed. The hardening boxes must not be made open on one side instead of on the end, for to lift the taps and draw them through the packing material from such a box when they are red hot is sure to spring them. Also no attempt should be made to use anything in place of charred leather.

In packing the taps in the packing material set them with the wrench end at cover end of box and lute the edges of the cover with fire clay mixed with water to the consistency of dough. Also use tongs of suitable shape for the work. In cooling the taps plunge them straight down into the bath quickly enough to prevent the oil from flaming up. Do not have the face directly over the bath, but protect the face as well as the hands and arms. It is best for this reason to have the top of the tank about 6 inches above the level of the floor, or to build a platform to stand on when dipping the work. It must be remembered that very much depends on how the pieces are machined. The steel, if it springs in annealing or machining, must not be straightened.—"American Machinist."

NOTES ON THE SERIOUS DETERIORATION OF STEEL VESSELS FROM THE EFFECTS OF CORROSION.

Lecture delivered by Mr. George Johnstone (Member) at the opening meeting of the Institution of Engineers and Shipbuilders in Scotland, 1901.

In the following notes I propose recording my experience in dealing with the serious deterioration of steel vessels from the

effects of corrosion. These notes apply more especially to the internal parts of the structure and to vessels employed within the tropics, which, owing to the change of temperature, the moist character of the atmosphere, and to the condensation of vapors containing active corrosive agents, suffer much more than those trading in a more temperate climate, and under less trying conditions.

My experience proves beyond a doubt that within the tropics, and under similar conditions, steel corrodes more rapidly and more unevenly than iron.

Oxidation may be said to have commenced from the moment the finished article leaves the hands of the manufacturer. And the magnitude and intensity of decay is governed by climatic conditions, quality of material, its initial treatment, and to the care taken in its preservation, after the vessel passes from the builder to owner.

The importance of a periodical inspection of the exposed parts of the structure cannot be overestimated. And special care should be taken on every available opportunity to attend to the parts that were previously inaccessible.

Having had considerable experience in dealing with the upkeep and repairs of a large fleet of steamers employed principally within the tropics, I have no hesitation in stating that, in my opinion, a large percentage of the money spent on these repairs was due to defective treatment. It is a well-known fact that in the early eighties, when steel may have been said to have finally replaced iron in ship construction, it practically received the same treatment that iron had previously received, although, owing to its greater strength, a considerable reduction was allowed in the scantlings of vessels built of steel. This reduction in the weight of material meant a corresponding gain in the vessel's deadweight capabilities and earning power when carrying deadweight cargoes, but it also meant that under similar conditions the life of the steel vessel would be considerably shorter than that of her predecessor built of iron. This, of course, is owing to the lighter scantlings and to the finer quality of steel being more intensely affected by corrosion, and also to the fact that the lighter the scantlings, the more rapid the decay.

Although it is not possible to entirely prevent corrosion, yet we have found that by a careful periodical inspection at short intervals, and by the removal of all rust, and by carefully coating the affected parts with a good anti-corrosive composition (which will be referred to later on), corrosion in many cases has been reduced to a minimum.

I shall firstly deal with local corrosion; although it only affects a small area, still, in my opinion, it is very important, not only because it is not easily detected and will, if neglected, produce serious local weakness, but also because of the fact that a large percentage of the money that has been spent on the repairs to vessels of thirteen years old and upwards has been due to local deterioration.

The most serious local corrosion takes place on the frames, reverse frames, and shell plating, immediately above the cement in water ways, and under the deck in wake of deck-stringer plates. As it is not easily detected unless carefully inspected, it is in a great many cases neglected, and oxidation, although slow in its initial stage, increases rapidly with age or with a decrease in the sectional area of the metal, so much so that I have known of cases where the flanges of the frame and reverse frames were completely corroded through before the steamer was nine years old.

The rapid deterioration of these parts is due, in a great measure, to the racking strains they are subjected to when the vessel is rolling in a seaway, causing the paint to fissure and thereby allowing condensed vapor and other liquids containing active corrosive agents to come in direct contact with the unprotected steel.

Corrosion is most intense in alleyways and bunkers abreast of machinery and boilers, and is owing to the great heat and to the fact that coal is very often bunkered in a very wet condition. This is especially so during the rainy season, when large quantities of water pass into the bunkers with the coal resulting in extensive evaporation and condensation, causing rapid oxidation not only on the parts already referred to but in a less degree throughout the whole bunker space, and if not carefully looked

after will, in the course of time, seriously affect both the transverse and longitudinal strength of the vessel in her most vital parts.

The mode of treatment I have adopted is to remove all rust, and have the parts thoroughly rubbed down with wire brushes and sandstone, and when clean and free from all damp and moisture to well cover the surfaces with two good coats of anti-corrosive composition. I may mention that in the bunker alleyways where corrosion is most intense, we have, in many cases, raised the cement around the frames and against the shell plating. This also applies to the between decks and orlops of steamers carrying native passengers and cattle. By adopting this plan, and having the cement well sloped, it not only prevents the water and urine or any other injurious liquid from lodging on the plating and frames above the cement, but it also prevents rust from forming on those parts previously affected. In a few cases the cement was found to contract, leaving an open space around the frames. This space was filled in with some of the composition referred to above. Reverting to local corrosion, the next in importance is the side plating and frames immediately behind the baths and water closets, and under scuttles and square ports. As you may be aware, it was the practice, until quite recently, to permanently line up the sides of cabins, baths, and water closets in passengers', officers', and engineers' quarters. Consequently, these parts, not being accessible, were neglected, and oxidation went on rapidly until the plates became perforated. To make these parts more accessible, it has been our practice, when opportunity offered, to panel the lining in wake of frame spacing under the ports and remove the same from behind baths and water closets, and I am pleased to state that since this has been done, and since more attention has been paid to the topside plating in general, and to the parts referred to in particular, it is the exception, not the rule, to see the topside plating of vessels under fourteen years of age, drawn in, in wake of rivets and disfigured by a number of outside patches. There are other parts that require special attention. I refer to the shell plating, frames, and reverse frames, behind the casing of all bilge, soil, and

scupper pipes, &c.; also to the bulkhead plating, immediately above the deck ends in the between deck and orlops, and where the decomposed cargo lodges between the ceiling and bulkhead over bilges and ballast tanks. I would also recommend that more attention should be paid to the space under close ceiling, extending from below the bilge stringers to the margin plate in ballast-tank steamers.

This space received practically the same initial treatment as the inside of the cellular double bottom. Yet it is common knowledge that the bilge water in many cases contains decomposed vegetable matter which acts in a most deleterious manner on the steel, if not properly protected.

To illustrate the importance of not only making these parts more accessible, but also in improving the present mode of protecting the metal, I may mention two cases that came directly under my observation a short time ago. Both steamers were of the cellular double bottom type and about five-and-a half years old. The closed ceiling was fitted in the usual manner, extending from a little below the bilge stringer to the margin plate. For the purposes of examining the condition of the parts not accessible, two strakes of planking were removed on both sides. It was then observed that a thick layer of rust had formed on the shell margin and bracket plating from the cement upwards, increasing in thickness on the flanged part of the margin plate, and on the reverse angles on bracket plate. To prevent, if possible, any further deterioration the ceiling was removed and the affected parts thoroughly scaled and rubbed down with wire brushes and sandstone. When the surface of the metal was found to be dry and free from all rust and moisture it was coated with three good coats of anti-corrosive paint, immediately the third coat was applied it was covered with dry Portland cement, and the carpenters proceeded at once to relay the ceiling; during this process the cement was pressed into the paint.

It may be mentioned that previous to removing the ceiling the wood appeared to be in very fair condition, but after removal the underneath side of the planking was found to be very spongy and rotten, and had to be removed throughout. Before laying the

new ceiling it was well coated with purified coal tar, care being taken to apply a thick coating of paint to the metal where the ceiling rested, to prevent water and moisture from getting between the wood and steel and thereby setting up corrosion.

I would suggest that all wood used for ceiling or sparring battens, or, in fact, for any purpose whatever that would bring it in contact with the metal, should be carefully coated with a good preservative to prevent decomposition. Pine and all other soft wood absorbs moisture to a great extent, and, consequently, when in contact with steel, promotes corrosion. This applies much more so when it is in a decomposed state, as, owing to its spongy nature, it becomes a most active corrosive agent.

No antiseptic should be used for preserving the wood that is at all likely to be injurious to the metal.

With reference to the cellular double bottom, the most extensive corrosion takes place in the ballast tank immediately under the boilers, so much so that in many cases deterioration has been of such a serious nature that a number of shipowners have entirely dispensed with the double-bottom compartment in the boiler space. The space containing the engines and boilers is undoubtedly the most vital part of the structure, and the inner bottom plate adds greatly to its safety. This being so, it is very important that nothing should be done that would in any way impair its efficiency as a watertight compartment.

It is satisfactory to note that the knowledge obtained from careful experiments made by engineers and others has resulted in a very considerable reduction in the magnitude and intensity of the corrosion affecting this part of the structure, so much so that steamers of thirteen and fourteen years of age are now being taken in hand to make good these defects.

Raising the boiler is undoubtedly a step in the right direction. Apart from the fact that it will prolong the life of the parts referred to, it will also facilitate repairs to the same. I would suggest going still further—that is, to subdivide the double bottom in machinery and boiler spaces in such a manner that the section immediately under the boilers could be kept dry and at all times accessible. I would also suggest that a proper system of ventila-

tion be fitted, and that the plating from the cement upwards be carefully coated with a good anti-corrosive composition that would withstand the heat.

Outside the boiler space internal corrosion is slight, as compared with what takes place under the boilers, and, with ordinary attention, should give no trouble.

Externally the inner bottom plating in holds corrodes rapidly if not properly protected, and my mode of treatment is simply a repetition of what was done in the bilges. I have used Stockholm tar instead of paint in several cases, but the results were not so satisfactory.

In these notes I have only referred to those parts that require special attention, and to others of a less important nature, with these exceptions, there should be no cause for anxiety.

It is very often the case when scaling or painting out the holds that, owing to the want of time or to neglect, nothing is done to ascertain the condition of the frames and plating behind the sparring battens and pipe casing. It is important that these parts should not be neglected.

I have a standing rule that on no account must paint be applied to a bare surface until it is perfectly clean and free from all damp and moisture. Applying paint to a damp surface will simply invite corrosion, as it will not absorb the moisture from the pores and surface, nor yet will it adhere to the metal.

External Corrosion.

Unsheathed Steel Weather Decks.—On no part of the structure have we found corrosion so extensive or so intense as on the exposed area of the weather decks. I have tried many patents in order if possible to preserve the deck plating from rust, but without success. Some of these compositions were not only said to prevent corrosion, but would also absorb all damp or rust remaining on the steel when it was applied. I believe the only effective means of protecting the deck is to have it efficiently sheathed, until someone invents a composition that will be absolutely watertight, impervious, elastic, and adhesive, and not affected by heat, salt or fresh water, or air.

The anti-corrosive paint referred to in these notes was made by mixing one part of white zinc to two parts of red lead and thinning it to the required consistency by applying boiled linseed oil. This mixture was found to be, when carefully applied, a good preservative, retaining its anti-corrosive qualities longer than any of the other pigments used. About six years ago, as a test, the inner bottom plating of a steamer was carefully coated with two coats of this composition. Previous to its application the plating was thoroughly scaled and rubbed down with wire brushes and sandstone. Immediately the second coat was applied it was covered with dry Portland cement, which was pressed into the wet paint during the process of relaying the ceiling. Four years after the ceiling was lifted and the plating examined and found to be in good order.

Of course this does not prove that a better composition is not in use; but I think it does prove that with ordinary pigments, when properly applied, the results are satisfactory. Referring to the space under closed ceiling, from bilge stringer to margin plate, I would suggest that the parts that are usually cement washed should be coated with a good bitumastic enamel.

In conclusion, I may say that the cost of keeping the holds and ballast tanks of a steamer of 5,400 tons gross in efficient order has been found to approximate to 3d. per ton per annum on the under-deck tonnage. This, of course, only includes cleaning, scaling, cement washing and painting.

MISCELLANEOUS NOTES.

THE BRITISH BOILER COMMITTEE is now considering the several alternative designs for boilers submitted by the shipbuilders tendering for the new armored cruisers of the *Devonshire* class. These new cruisers are to be of 10,200 tons displacement, or 10 feet longer than the vessels of the County class, and the engines are to indicate 22,000 I.H.P. to give a speed of 23 knots. Only 1,890 tons as a maximum can be allowed for machinery, and the several firms were asked to submit designs and prices for installations of Yarrow, Dürr, Niclausse and Babcock & Wilcox

boilers, and also for certain combinations of cylindrical and water-tube boilers, embracing various systems of draft. These designs are now before the Boiler Committee. Some delay must be incurred in adjudicating on the combinations. There is naturally considerable discrepancy in price between the different firms. A Clyde firm quotes the Yarrow installation at £48,000 less than the Niclausse, while another Clyde firm quotes the Yarrow £5,000 higher than the Niclausse. A third firm quotes the Dürr at £10,000 less than the Yarrow, while a fourth quotes the price £32,000 higher. One firm places the ship with Babcock & Wilcox boiler £13,000 below the Yarrow, and another £24,000 above it. It will be no easy job to decide among such differences.

THE BELLEVILLE BOILER has been hit rather hard over the last British Channel Fleet full-speed trials. Here are the figures:

Course: Palma to Gibraltar—342 miles.

Ship.	Average speed in knots.
Mars, battleship,	16.2
Niobe, cruiser, Belleville,	16.1
Jupiter, battleship,	16
Hannibal, battleship,	15.9
Magnificent, battleship,	15.7
Majestic, battleship,	15.5
Prince George, battleship,	broke down.

The *Prince George's* engines are, as we mentioned some time ago, said to be in a bad way. Those of the *Niobe* are not, and her reported breakdown is not confirmed. How comes it that one battleship beat her, and that the others very nearly kept up? In the case of the *Hyacinth-Minerva* race, other things than boilers could be reckoned as contributory causes, but in the case of the *Niobe* we know of nothing wrong with the engines in any way.

THE NEW ENGLISH BATTLESHIPS AND CRUISERS proposed by the Admiralty are to adopt electrically-driven machinery; 100

volts at lamp terminals is the new standard voltage. Telephones are to be still further adopted, and some additions to the number of electrically-driven fans for ventilation, and electric capstans are proposed.

THE SPECIAL BOILER COMMITTEE have decided to repeat the program and steam trials of the cruisers *Hyacinth* and *Minerva*, including the race to Gibraltar and back. Before this, however, the vessels are to be steamed over the deep-sea course off the Cornish coast, at speeds of 16 to 18 knots and at full natural-draft speed. After three runs over the course at each of these speeds the *Minerva* will go to Stokes Bay for a series of runs over the measured mile at 10, 13, 17 and 18 knots speed. She will commence her trials next week, but the *Hyacinth* will be delayed for a week or two, owing to defects which are being repaired at Devonport Dockyard.

SUBMARINE BOATS.—The Paris "Matin" has published an article by M. Lockroy, in which the ex-Minister of Marine gives his opinion on submarine boats. It seems to him that henceforward these craft will be terrible instruments of attack and defense; but he considers that there is still room for progress as regards habitability and range of action. Reviewing the type of vessels which are purely and simply submarines, and are propelled exclusively by electricity, with a limited range of action, M. Lockroy expresses the opinion that this class must be used solely for coast defense work, while it would be impracticable to tow them. For carrying on operations at a distance, the writer thinks it would be preferable to rely on submersible boats, which have the drawback that they cannot be submerged very quickly. He considers, nevertheless, that the time occupied by this operation—eight minutes—is sufficiently short, and, moreover, it will soon be reduced to five minutes. M. Lockroy finally comes to the conclusion that it will only be possible to fight against submarines when the steering of balloons has been discovered, the black form of the vessels being very easily distinguished in the water from a certain height.

COALING SHIPS AT SEA.—The British line-of-battle ship *Trafalgar* and the collier *Muriel* have completed a series of official trials undertaken to test the utility of the Temperley-Miller marine cableway for coaling ships at sea. Working under contract conditions, the apparatus placed an average of 30 tons of coal per hour on board the *Trafalgar*, while that vessel was steaming at 10 knots. At a slower speed and with the cableway shortened, 40 tons per hour were transhipped. The Admiralty officials who witnessed the trials were so well satisfied with them that the cableway is to be given a trial with the fleet.

THE FRENCH SUBMARINE *Silure* has recently been submerged at a depth of about 140 feet. At this depth the pressure, according to reports, only compressed the boat $\frac{1}{25}$ inch. What particular object is served by being at such a depth is not very clear. It is about 110 feet below the bottom of the average battleship.

LIQUID FUEL.—The Consulting Engineer of the Russian Steam Navigation Company read an interesting paper recently at a meeting of engineers in Odessa, on the subject of oil fuel for steamers, in which he pointed out that Russia was the pioneer in the use of oil for steam generation at sea. The largest vessels plying in the southern reaches of the Volga have long ago discarded all other fuels in favor of ostatki, or residue; while the vessels of the Eastern Company, on the Caspian Sea, though built with coal-burning furnaces, and using coal alone on their maiden voyage from Great Britain to Aserakan, invariably have their furnaces altered and adapted for the use of oil on their arrival in the Caspian. Some years ago the Russian Steam Navigation Company determined to give the vile looking "ostatki" a trial on three of their vessels, and the experiment has given most gratifying results. Cost for cost, the experiment has demonstrated in the clearest manner the advantage of oil fuel over coal, the cost of oil per mile amounting to only one-third that of coal. Further, on the score of cleanliness, the

superiority of oil is abundantly proved, a consideration of great importance in vessels of the passenger class, where cleanliness means increased comfort. Several other advantages were noticeable at the trial, not the least of which, in the eyes of the engineer, was the easy and equable regulation of the heat over the whole heating surface, the comparatively easy manipulation of the fuel itself under steam pressure, and the saving of labor and waste in the stokehold. Experiments in a similar way with ostatki are to be carried out shortly on certain ships of the Russian Navy.—"Marine Record."

PRACTICAL TEST OF FUEL OIL.—Particulars are published in the German papers of results obtained in a practical test of the value of fuel oil in the generation of steam on an ocean steamship, recently made in the case of the North German Lloyd vessel *Tanglin* on a voyage from Singapore to Sydney, a distance of nearly 5,500 miles. The *Tanglin* was chartered to convey to Kerguelen Island the dogs, equipments and coals for the German Antarctic expedition. She is a steamship of about 2,000 tons capacity, built last year for the North German Lloyd by Workman, Clark & Co., Belfast. She was intended for the East Indian trade and was fitted with apparatus for burning oil and saving labor in the stokehold. Her ordinary bunkers are used for the storage of the oil, all apertures being closed and made watertight, and the oil is pumped in from craft lying alongside. The oil used by the *Tanglin* came from Borneo and was taken on board at Singapore. By the method adopted on board this boat the oil is converted into spray and blown on the grates by means of injection tubes and nozzles pierced with fine holes. The service of only one man is required in feeding the fires, and the supply of oil and the steam pressure are always directed to the required point by means of special valves. The *Tanglin's* bunkers are so constructed that they can be used either for coal or oil.

Compared with the old system of coal stoking the following results were arrived at: The weight of each day's supply of fuel was much less, and a great saving of labor was effected, inasmuch

as only one man per watch was required instead of five. The *Tanglin* took 350 tons of oil on board for her voyage (her capacity for coal is 300 tons), and with a consumption of 13 tons per day an average speed of 11½ knots per hour was attained. This means an increase in the speed amounting to a knot per hour. The most disagreeable task connected with coal stoking is cleaning out the furnaces; when oil is used there is no cleaning to be done.

The chief engineer on board the *Tanglin* expressed his entire satisfaction with the result obtained. He is of opinion that liquid fuel will soon be extensively used on board great ocean steamships, and in his report to the directors of the Lloyd company he strongly advocates the adoption of the new method. The *Tanglin* used coal on her outward voyage as far as Singapore, and after shipping oil there she proceeded to Bangkok, consuming 13 tons of oil daily, against 18 tons of English and 20 tons of Japanese coal. The report adds that the oil gives off no odor and that the heat in the engine room was quite insignificant, while the required pressure of steam was maintained with ease. As regards the cost, the oil was put on board at Singapore at 30 shillings per ton, and the whole quantity—350 tons—was got into the bunkers in three-quarters of an hour. The cost of coal at the same port, brought alongside, was 25 shillings per ton.

The mere comparison of the daily expenditure for fuel, namely, 20 tons of coal at 25 shillings, equal to £25, against 13 tons of oil at 30 shillings, equal to £19 10s., a saving of £5 10s. per day in favor of fuel, does not represent the whole gain to the ship owner. There is the extra freight that he may earn as represented by the difference between 13 tons and 20 tons deadweight of daily consumption, which, on a twenty days' run, would be equal to 140 tons. There is also the extra measurement cargo which he may carry by stowing the fuel oil in the ballast tanks and peaks and there is the saving of firemen and of time in bunkering ports. It is evident that 350 tons of oil bunkers taken on board in three-quarters of an hour can find no near comparison in the case of any recorded instance of coal bunker-

ing, and the cleanliness of taking on board liquid fuel in comparison with dirtying the decks and passenger accommodation due to coal bunkering is also an appreciable financial asset upon routes where passenger competition is at all keen. The extra speed of the *Tanglin* when using oil fuel illustrates the experience that has been reported in respect of other vessels, namely, that boilers which are hard to steam with coal become quite easy to steam with oil, on account of the greater intensity of the heat generated by the new fuel.—"Marine Review."

SHIPS.

UNITED STATES.

The Naval Program for 1903, as presented in the Naval Appropriation Bill, involves the expenditure of $77,659,386, or $442,404 less than last year. For the increase of the Navy, provision is made for building two first-class battleships of 16,000 tons displacement, at $4,212,000 each, exclusive of armor and armament; two first-class armored cruisers of 14,500 tons, at $4,659,000 each; and two 1,000-ton gunboats at a cost not exceeding $3,802,000. The report says that the 138 vessels of our new Navy, built and building, cost $235,082,209; but out of this number our naval strength lies practically all in the 18 battleships, 8 armored cruisers and 21 protected cruisers. The bill leaves it discretionary with the Secretary of the Navy to build any or all of the new ships in Government yards; but it requires him to build at least one in such yard and to keep a close account of cost for labor and materials, so that the cost by Government work and by contract can be compared.

Barry.—This torpedo-boat destroyer was launched from the works of Neafie & Levy in Philadelphia, on March 22. Immediately after her launch she proceeded down the Delaware River under her own steam, and after a three hours' run, during which her machinery worked admirably at from 125 to 160 revolutions, she returned to the builders' yard.

Her principal dimensions are:

Length on L.W.L., feet	245
Beam, feet and inches	23–7½
Mean draught, feet and inches	6–6
Displacement, tons	420
Designed speed, knots	28
Required trial speed, knots	26
Engines, type	2 vert. inv. triple

Engines, cylinders, diameter, inches	20½, 32, 2 of 38
stroke, inches	22
revolutions	327
steam pressure, pounds	300
I.H.P.	8,000

Dale.—This torpedo-boat destroyer has undergone her standardizing and acceptance trials over the Barren Island course on May 3. Upon the first attempt at running off the standardizing trials, while making about 27 knots, one of the H.P. piston rods became hot and the trials had to be abandoned. On the following Saturday, the trials were finally run off, the vessel reaching a speed of 28⅛ knots during the preliminary trials, and 26.6 knots during the final trial. The detailed report of these trials has not yet been received, but will be given in full in the next number of the JOURNAL.

The *Dale* is an exact counterpart of the *Decatur*, which was described in our February issue.

Fulton.—When the submarine boat *Fulton*, of the Holland T. B. Co., which sailed from New York April 28, arrived at the Delaware Breakwater on April 29, an explosion occurred, shortly after she came to anchor, in a gasoline tank. Of those on board, Lieutenant Arthur MacArthur, U. S. N., was cut about the head by bits of iron; Lieutenant Oscar Cohen, of the Austrian Navy, was hurled violently against an iron railing, and his back was injured; C. B. Miner and Harry Moore, assistant engineers, had their faces cut by iron, and Moore was nearly asphyxiated by gasoline fumes, as it was some time before he was rescued. Charles Rechtal, a gunner, sustained injuries about the head. Captain Frank T. Cable, with First Mate H. H. Morrell and Charles Bergh, was on deck steering the boat, and Lieutenant C. P. Nelson, U. S. N., was passing up through the conning tower to the deck, when the explosion threw him clear out on deck and sent the nine men inside the boat into a heap. Distress signals were set, and in a few minutes boats from the maritime station rowed alongside and transported the injured to the hospital at Lewes, where at last accounts they were doing well.

The cause of the explosion, up to the present, is said to be a

mystery. The machinery of the boat appears to be uninjured, the injuries to the men being caused mostly by splinters from the woodwork.

Lieutenant MacArthur is quoted as saying that he thought it possible that the explosion was caused by an accumulation of air in the tanks of gasoline. In the opinion of Mr. Fred. H. Verdu, agent of the Holland Torpedo Boat Company, the explosion was caused by an accumulation of sulphuric acid gas, with possibly other gases, that had formed under the airtight flooring that covered the battery. The explosion of this gas blew up the wooden flooring and wrecked the battery, which covers almost the entire bottom of the boat, and consists of sixty cells, weighing 1,000 pounds each. The engines and the gasoline tanks were not injured in the least.—"A. and N. Journal."

Proposed Light-Draught Gunboats of about 200 tons displacement and 9½ knots speed for use in the Philippines.—It is proposed to make the machinery of these vessels as simple, strong and durable as possible, with reasonable economy of coal consumption and weight of machinery.

The boat to have twin screws. The engines to be of the vertical, compound type, having H.P. cylinders about 9 inches and L.P. cylinders 18 inches, with a stroke of 15 inches. The I.H.P. to be about 200 at 200 revolutions and a boiler steam pressure of about 100 pounds.

The circulating, air, feed and bilge pumps to be attached to the main engine. Independent main and auxiliary feed pumps to be installed for use when required at sea and on the condensers in port when the dynamo is used.

There will be two condensers, one forming the back frame of each engine. The cooling surface in each condenser to be about 150 square feet.

Steam will be supplied by two single-furnace Scotch boilers, similar to those used on the *Wilmington* and *Helena*, each having a diameter of 7 feet 6 inches and a length of 8 feet 6 inches. The total grate surface will be 40 square feet and the heating surface 1,120.

An evaporator of Bureau type, having a capacity of about 800,

and a distiller of 200 gallons, will be installed. Suitable pumps will be installed for working distilling plant.

The total weight of machinery, stores and spare parts will be about 36 tons.

Gunboats of 1,000 I.H.P., Machinery for.—For the proposed 1,000-ton gunboats for use in the Philippines, machinery is proposed similar to that fitted in Gunboat *Marietta*, but of somewhat greater power, being of 1,000 I.H.P. instead of 800, which should give a speed of about 13 knots in smooth water.

The boat to have twin screws. The engines to be of the vertical, triple-expansion type, having cylinders of the following diameters: H.P., 9 inches; I.P., 15½ inches; L.P., 25½ inches. The stroke will be 21 inches. The I.H.P. will be about 1,000 at 225 revolutions and 250 pounds of steam.

The main air, feed and bilge pumps will be worked from the main engine. One independent, centrifugal circulating pump will be fitted for each condenser. A hotwell pump will be fitted to work on either condenser and be used as an auxiliary air pump when in port. Auxiliary feed, fire and bilge pumps will be provided.

Each engine will have a separate condenser forming the back frame. The cooling surface will be about 750 square feet for each condenser. Steam will be supplied by the Babcock & Wilcox boilers, having a total grate surface of 100 square feet. The heating surface will be about 4,250 square feet. With natural draft this should give, with all the usual auxiliaries in operation, about 700 I.H.P. continuous steaming, giving a speed of about 11 knots under ordinary conditions at sea.

Two evaporators of Bureau type, having a capacity of about 1,500 gallons each, and two distillers, having a capacity of about 1,000 gallons each, will be installed.

The weight of machinery will be about 125 tons.

Hopkins.—This torpedo-boat destroyer was launched from the works of the Harlan & Hollingsworth Co., Wilmington, Del., on April 24:

Her principal dimensions are as follows:

Displacement, tons	408
Length on L.W.L., feet	244
Beam, feet and inches	24-6
Mean draught, feet	6
Engines: number	2
type	vert., inv., tr. exp.
cylinders, H.P., inches	22
I.P., inches	32.5
L.P., inches	2 of 34
stroke, inches	18
designed revolutions	400
H.P.	7,200
steam pressure	240
Boilers: type	4 Thornycroft.
heating surface, square feet	17,612
grate surface, square feet	294

Mohawk.—The new revenue cutter *Mohawk* was successfully launched from the shipyard of the William R. Trigg Company, Richmond, Va., recently. She is 205 feet long, 32 feet beam and 17 feet deep. Her engines will have cylinders of 25, 37½ and 56½ inches diameter by 30 inches stroke. Steam will be supplied by four Scotch boilers. The *Mohawk* will be assigned first of all to the West Indies, but her eventual station is the Pacific.

Perry.—This torpedo-boat destroyer, built by the Union Iron Works, of San Francisco, made a successful trial on May 7. The original speed required was 28 knots, but this had been lowered by the Government to 26 knots.

On the trial, the average speed made was 27 knots, with an average revolutions of 346.7 per minute, and an average I.H.P. of about 8,030.

The principal data of the *Perry* are as follows:

Length on L.W.L., feet	245
Beam, feet and inches	23-7½
Mean draught, feet and inches	6-6
Displacement, tons	420
Engines—type	2 vert., inv., triple
cylinders, diameter, inches	20½, 32, 2 of 38
stroke, inches	22
revolutions (designed)	327
steam pressure, pounds	300
I.H.P.	8,000

The details of the trial have not yet been received.

Stewart.—At the works of the Gas Engine and Power Company, Morris Heights, New York, was launched the destroyer *Stewart*, on March 10.

Her principal characteristics are:

Length on L.W.L., feet	245
Beam, feet and inches	23–7½
Mean draught, feet and inches	6–6
Displacement, tons	420
Engines, type	2 vert. inv. trip.
cylinder, diameter, inches	20.5, 32, 2 of 38
stroke, inches	22
designed revolutions	327
steam pressure, pounds	300
I.H.P.	8,000

CHILI.

Chacabuco.—The *Fourth of July*, a sister of the *Takasago*, which figures in the current "Naval Annual," under the head of Japan, as "unnamed, building," has been purchased by Chili, and named *Chacabuco*. To Chili the *Chacabuco* should prove extremely useful. She is very fast—some 24 knots—and so will be a useful addition to the small, swift fleet of Elswick vessels that Chili owns.

Thompson, Tarpa, O'Brien.—Three destroyers are reported purchased by Chili—*Capitan Thomson*, *Capitan Merino Tarpa* and *Capitan O'Brien*. Whence they have come is not stated. *Capitan Thomson*, we fancy, is an old friend, one of the Yarrow couple of extra boats of the *Ingeniero Hyatt* class, sent out to Chili in pieces and put together at Balcachuamo in 1898. She is a fine 130-ton boat. Probably the other two are later sisters ordered, and now completed in the ordinary course.—London "Engineer."

New Ships.—The two warships which the Chilian Government have ordered from Barrow and Elswick, are to measure 435 feet in length, with a breadth of 70 feet. Their engines are to develop 25,000 horsepower, and their armament will comprise four 10-inch guns; fourteen 7.5 quick-firers, and a number of smaller quick-firers.

ENGLAND.

Good Hope.—H. M. S. *Good Hope* has just completed her official contract steam trials, and has attained most satisfactory results. She is a first-class armored cruiser of 14,100 tons displacement, built by the Fairfield Company, and delivered two months within contract time, and the three other ships of the class, now almost ready, are the *Drake*, built at Pembroke Dockyard; the *Leviathan*, at the Clydebank Works of Messrs. John Brown & Co., Limited; and the *King Alfred*, at the Barrow-in-Furness Works of Messrs. Vickers, Sons & Maxim, Limited. The *Good Hope*, on her thirty hours' trial at three-fourths power, attained a speed of 22.08 knots, and on her full-speed trial maintained a power of 31,071 indicated horsepower, steaming for eight hours at 23.05 knots—a speed never before reached by any British ship other than torpedo craft, while, if equalled by foreign ships, it has only been on shorter trials and at the expense of some of the necessary fighting qualities. The *Good Hope*, a name given in recognition of South Africa's liberal contribution to the Navy, therefore appropriately marks the greatest achievement of British naval construction at a time when Sir William White severs his connection with the Navy. There is thus a temptation to glance briefly at the progress thus signalized and made under Sir William's *régime*, in association with Sir John Durston as engineer-in-chief of the fleet.

The *Imperieuse* and her consort, the *Warspite*, are typical of the latest cruisers designed before Sir William White went to the Admiralty, and the increase in length from 315 feet to 500 feet has brought a development in displacement tonnage from 8,400 tons to 14,100 tons. This growth in what has been conveniently called the capital of the naval designer has been wisely spent, for in speed—a first desideratum for the cruiser—there has been a gain from 16.7 to 23 knots, which has called for three times the power, 30,000 indicated horsepower, as compared with 10,000 indicated horsepower, and that, too, without anything like doubling the weight of machinery. Thus the increased displacement had been devoted in large measure to improving offensive and defensive qualities. The area protected by armor

has increased about five-fold, with metal of much greater resistance to attack by projectiles; the collective muzzle energy of one minute's fire of guns in the primary battery has increased six-fold, from about 120,000 foot-tons to 713,000 foot-tons. The bunker capacity has increased more than two-fold, and the radius of action at 10 knots, notwithstanding the greater weight to be driven, has become more than double, so that with something less than twice the displacement and cost, the modern ship has at least thrice the fighting efficiency.

The *Good Hope* may be described as a belted *Powerful*, for the principal dimensions are practically the same—500 feet long, 71 feet beam, and 26 feet draught, although the displacement is 100 tons less—14,100 tons; but the chief difference is that while the earlier ship was a protected cruiser, the new vessel has a broadside belt 396 feet long, and for about 280 feet this is 11 feet 6 inches broad and of 6 inches to 4 inches in thickness; it increases in width at the forward end to 24 feet, but tapers to 2 inches in thickness. At the after end of this belt there is a 5-inch bulkhead. Thus only 105 feet of the broadside, at the stern, is without armor plating, but there is a 2½-inch deck covering in steering gear, capstan machinery and magazines. Within the armored section there are two protected decks, the upper 1½-inches thick, and the lower 1-inch. In addition to this advantage in defensive quality, the *Good Hope* has, as we have already stated, attained a speed of 23 knots as compared with the 22 knots of the earlier ship. She has four more 6-inch guns—sixteen in all, as well as two 9.2-inch breech loaders—and, moreover, the guns are of higher ballistical power; the new 9.2-inch weapons developing an energy of over 19,000 foot-tons, and the 6-inch weapons of 5,340 foot-tons. The *Powerful* is now, however, being fitted with the four additional 6-inch weapons. The *Good Hope's* 9.2-inch guns are within barbettes of 6-inch armor, and are protected by large gun shields 6 inches thick on the front, while the quick-firers are mounted within a series of two-story casemates with 5-inch hardened armor on the face, and 2-inch on the rear. The conning tower is of 12-inch armor,

with a tube of 7-inch armor encircling the communication and controlling gear.

The new ship is thus superior in all qualities—speed, offense and defense—to the *Powerful*, and it is not without interest to note the directions in which there has been such economy in weight as rendered possible of realization this satisfactory result. In the first place, the *Good Hope* is not wood sheathed and coppered, as was the case with the earlier vessels. It is true such sheathing confers an advantage in the event of long commissions, as the bottom remains longer clean; but even this benefit is very variable, and the excellent docking facilities now available suggested that the design should not be penalized by the weight of something like 400 tons, which this sheathing involves. Again, there is no poop; nor is there a boat deck between the fore-and-aft bridge, as was the case in the earlier ships. A shelter deck is provided for a short distance in the waist of the ship at the navigating bridges, and a longitudinal gangway between the bridges is provided; but for the most part the bulwarks are only hammock-berth high, as used to be the case in ships built prior to 1894, the *Majestic* class being the first with the boat deck. This deck, it is true, increased the freeboard to the extent of about 4 feet, and the poop gave a higher gun platform to the stern-chasing 9.2-inch gun. But apart from the weight these structures directly involve, they materially affect the stabilty conditions and also the size of the ship to a very considerable degree. The area of target presented to the enemy is lessened by the design now adopted, and this was a point often raised against the *Powerful*.

At the same time the appearance of the ship is smarter. The decreasing freeboard towards the stern improves the rake. The absence of cowls is notable; the *Good Hope* is the first of the later ships in which these have been dispensed with. This also decreases weight and air resistance, improves the observation from the bridge, but, more important still, reduces the amount of splinters brought down on the deck from the effect of projectiles doing destructive work amongst the top hamper. Wind sails are supplied to take the place of the cowls when required

for supplying air to the fans in the shafts communicating with with the machinery spaces, and experience will show whether these are effective. As to appearance, it should be noted that while the foreward funnel, into which eight boilers exhaust, is circular, the greater area required for the others, owing to more boilers communicating with them, is provided by making them oval on plan, with one axis of the ellipse equal to the diameter of the forward funnel; thus all four appear equal on the broadside view. The funnels are 90 feet high above the deadplate. It will be noticed also that there are no military tops on the masts; their absence also helps the stability conditions.

A walk through the ship discovered several interesting departures in the mechanical equipment. Of first importance is the fitting now of a sighting hood upon all the upper casemates. Formerly observation was through the more or less limited area of the gun port, and thus the field of vision, especially with telescopic hoods, was very small; the change enables the captain of the gun to see all around without exposing himself. Although hydraulic power has been substituted for electric motors in the 9.2-inch gun mountings, electricity is in extended use, and the hoists for the 6-inch guns, working in armored tubes communicating within the casemates, are electric. Some fourteen fans for ventilating the habitable quarters are also electrically driven, and the after capstan is similarly operated, with the result that there are no steam pipes abaft the main machinery and dynamo rooms. There are four dynamos of 480 ampères at 100 volts. Hydraulic power is being used for the boat-hoisting gear. This is the first ship since the *Victoria* and *Sans Pareil*, except the torpedo-boat repairing-ship *Vulcan*, which has her boat derrick associated with hydraulic power. There is a ram in the hydraulic room below for working the purchase, and a three-oscillating cylinder three-crank winch to deal with the topping lift through cable rope winding on a coned as well as grooved barrel. The cone makes the turning moment more uniform, and the whole system, with its valves and levers concentrated on deck, operates at a higher speed than with steam gear. The anchor stowage is also different. Napier's well-

known gear is in use, but the anchors themselves are stowed horizontally on the side of the ship, instead of vertically or on a horizontal bed or bill board on the upper deck, as in previous ships. The difference is largely a result of increased freeboard —the forecastle gives greater height, and the anchors when thus stowed are not so near the water. The anchor is "boused to," or made snug into the ship's side by a rod with a hook, which, after it has caught the gravity band, is worked in by a screw. Screened lights are fixed, so that at night illumined portholes cannot betray the presence of the ship. These lights are fitted in metalcones, over which there slides a bellmouth cover, shading the light on all sides, but reflecting it downwards.

The machinery occupies one-half of the length of the ship—to be exact, 247 feet 6 inches—the four stokeholds being each 45 feet, and the engine room 67 feet 6 inches, while at the forward end there is an athwartship bunker about 8 feet wide, in addition to the longitudinal spaces abreast the machinery and boilers, the total coal capacity being thus 2,590 tons=7,000 miles radius of action at 14 knots; while the reserve feed tanks carry 150 tons of water. With the exception of a torpedo room forward, the remainder of the under-water structure is given up to magazines. In the machinery, as in the ship, there are several interesting departures of note. Each set of engines consists of four cylinders, working triple-compound. The order of cranks is according to the usual Yarrow-Schlick-Tweedy system, and here it may be said that the balancing proved most effective. A low-pressure cylinder is fitted at either end, with the high-pressure cylinder (43½-inch) close against the forward low-pressure (81½-inch), and the intermediate (71-inch) in similar close proximity to the after low-pressure (81½-inch). The stroke is 48 inches. At the extreme ends are the treble-ported slide valves, three ports being adopted to give sufficient steam admission with the relatively short travel of 8 inches. The single piston valve and double piston valves for the high-pressure and intermediate-pressure cylinders respectively are in the center. These have a travel of 12 inches. The intermediate-pressure valves are suspended from a crosshead with one valve spindle, as is usual; but here the crosshead is within

the valve casing, so that there is but one stuffing box, instead of two, where the crosshead is placed externally, and there is no chance of difficulty arising owing to great ranges of temperature between the valves and the outside connections. The cylinders are steam jacketed, but, excepting for 15 hours on the low-power trial, the only use to which these were put was to warm up the cylinders preliminary to starting. Each low-pressure cylinder exhausts into a separate condenser with its own air pump, and cross-connections are provided for connecting or isolating them. The total cooling surface is the same as with a single condenser for each engine, the area being 32,000 square feet, equal to 1.066 per indicated horsepower. The air pumps are 33 inches in diameter, and, worked off the crossheads, have a 16-inch stroke. While the main cylinders are supported in front by the usual forged-steel columns, the arrangement at the back is not the ordinary A-frame, but instead there are two vertical castings, and on these are cast brackets at top and bottom, carrying large-area guide-plates. Thus the cylinders are supported at four points, insuring greater rigidity.

Some of the dimensions may here be given, as they are of interest, in view of the power indicated on the weights possible in warship machinery. Crank and thrust shaft, 21 inches in diameter; tunnel shaft, 19½ inches; stern-tube shaft, 21 inches, each with 11-inch hole bored in center; propeller shaft, 21 inches, with 12-inch hole; length of connecting rod, 8 feet; mean diameter of high-pressure and intermediate-pressure connecting rods, 10¾ inches; of low-pressure, 8¾ inches; diameter of piston rods, high pressure and intermediate pressure, 11½ inches; low pressure, 9¼ inches; diameter of crankpins, high pressure and intermediate pressure, 24 inches; length, 2 feet 6½ inches. The low-pressure crankpins are 24 inches in diameter, and 20½ inches long. As to the main bearings, four are 3 feet long, and two 3 feet 3 inches. The reversing shaft is 10 inches in diameter, and the valve spindles 5½ inches in diameter. The only point as to metal which may be noted is that the liners of the high-pressure and intermediate-pressure cylinders are of forged steel, and those of the low-pressure cylinders cast iron.

There are 43 Belleville boilers, with 382 elements in all. The total heating surface is 71,964 square feet, and the grate area 2,314 square feet—a ratio of 31.1 to 1; and here it is interesting to add that the heating surface per indicated horsepower is 2.32 square feet, while 13.4 horsepower was got per square foot of grate area, the fuel consumption being equal to 25.7 pounds per square foot of grate. The total weight of machinery complete, including water in the boilers, is 2,540 tons; and on the full-power trial 12.23 indicated horsepower was developed per ton of machinery complete, and 47.6 indicated horsepower per ton of boiler, including water (652 tons).

And this brings us to the trials themselves. These, it may be said at the outset, have proved eminently satisfactory, and Sir John Durston, K. C. B., the Engineer-in-Chief of the Navy, and the Fairfield Company, are to be congratulated on the results. The first trial at one-fifth power was a comparatively simple test, and little need be said of it, except to point out that the results show that the vessel can steam 7,000 miles at 14 knots speed without re-coaling, and may thus go from Madeira to the Cape easily. Only 12 boilers were alight. The results may be tabulated:

REPORT OF THIRTY HOURS' COAL-CONSUMPTION STEAM TRIAL AT ONE-FIFTH POWER OF H. M. S. "GOOD HOPE," FEBRUARY 18 AND 19, 1902.

	Ford.	*Aft.*
Draught of water, feet and inches	26–2¾	26–2¾
Steam in boilers, pounds	239	
	Star.	*Port.*
Vacuum, inches	25.5	26.6
Revolutions per minute	70.8	71.4
Mean pressures, high, pounds	41.2	38.9
intermediate, pounds	16.8	15.8
low, forward, pounds	5.1	5.04
low, aft, pounds	4.8	5
Indicated horsepower, high	1,049	999
intermediate	1,141	1,082
low, forward	455	454
low, aft	424	450
Mean total I.H.P.	3,069	2,985
collective I.H.P.	6,054	
Speed of vessel, knots	14.5	
Coal consumption per I.H.P. per hour, pounds	1.87	

The second trial of 30 hours' duration at three-fourths of the full power was a more crucial test, but was carried through without any hitch. The ship experienced a heavy Atlantic swell, but behaved admirably, the absence of vibration being specially noteworthy. We tabulate the results, and here may point out that the cut-off in the high-pressure cylinder was at 60 per cent. of the stroke, while on the low-power trial it was 40 per cent. During the trial several runs were made over a 22-knot course, determined by cross bearings, on the English coast, west of Portland, and the results were as follows:

SPEED TRIALS AT THREE-QUARTER FULL POWER ON 22-KNOT COURSE.

——	Time.		Speed.	Revolutions.	Indicated horsepower.
	min.	*sec.*	*knots.*		
First run	59	3	22.35	107.2	21,877
Second run	59	45	22.09	109	22,654
Third run	60	31	21.81	109.6	22,508
Fourth run	58	5	22.72	110.5	22,830

Mean of means, 22.09 knots.

The mean power developed during the 30 hours' run was 22,703 indicated horsepower, and this is about the mean for these four runs. The propeller efficiency was high, the slip being only 10.2 per cent. The propellers are 19 feet 2 inches in diameter, and have a pitch of 22 feet 9½ inches. The coal consumption, it will be noted, is about the same as on the one-fifth power trial.

REPORT OF THIRTY HOURS' COAL-CONSUMPTION STEAM TRIALS AT 22,500 INDICATED HORSEPOWER OF H. M. S. "GOOD HOPE" IN THE ENGLISH CHANNEL, FEBRUARY 20 AND 21, 1902.

	Förd.	*Aft.*
Draught of water, feet and inches	26–2	26–2
Steam pressure in boilers, pounds	268	
	Star.	*Port.*
Vacuum, inches	26½	27¼
Revolutions per minute	109	110.7
Mean pressures, high, pounds	95.4	95.8
intermediate, pounds	38.6	37.9
low, forward, pounds	12.74	11.94
low, aft, pounds	13.05	13.36
Indicated horsepower, high	3,743	3,819

Indicated horsepower, intermediate	4,039	4,029
low, forward	1,750	1,666
low, aft	1,793	1,864
Mean total I.H.P.	11,325	11,378
collective I.H.P.	22,703	
air pressure	.....	
Speed of vessel (mean of four runs), knots	22.09	
Coal consumption per I.H.P. per hour, pounds	1.83	

One point in connection with this, as of all the trials, has reference to the use of the exhaust steam from the auxiliary machinery for evaporation or other useful purpose, instead of passing it into the condenser. On this, as on other modern ships, this exhaust, owing to the high initial pressure and the fact that the auxiliary engines are worked mostly on the simple or compound principle, has much latent heat or energy, and thus arrangements are made to exhaust into the low-pressure receiver, the evaporators, or the auxiliary condenser. The resultant economy has proved to be about 5 per cent., at low powers when used for the evaporators, and this was borne out on these trials, when it was similarly used instead of live steam from the boilers. Thus on the one-fifth trial 26 tons were required for make-up feed, equal to 3.43 tons per 1,000 horsepower per 24 hours; on the 30 hours' trial at 75 per cent. power 132 tons, or 4.65 per 1,000 indicated horsepower per 24 hours, and on the full-power trial 45½ tons, or 4.39 per 1,000 indicated horsepower per hour; all of this was made up by the exhaust.

There are four evaporators, their total weight being 37 tons, including the pumps, &c., in connection. This point is of some importance, because it has been urged that the weight of evaporators necessary to make up the feed water nullifies the gain in the weight of water-tube steam generators, as compared with the cylindrical boiler. The evaporating capacity is 270 tons of fresh water per day, and experience shows that on this trial 5 or 6 tons may be made per 1,000 horsepower developed by the main engines from the exhaust of the auxiliary machinery necessarily in use at the same time.

The auxiliaries number about 75, and include 8 Weir feed pumps, 4 main circulating Allen pumps, 2 auxiliary circulating

pumps, 2 auxiliary Lamont feed pumps, 18 stokehold fans, 2 hotwell Weir pumps, 4 fire and bilge Weir pumps, 4 dynamo engines, 2 air compressors, 4 furnace-blowing engines, 1 Hall refrigerator, 4 Caird and Rayner evaporators, 2 distillers, 2 Napier Brothers steering engines, 8 ashhoists, 2 Napier Brothers coalhoists, 1 workshop engine, &c. The power of these various auxiliaries is indicated by the fact that the cooling surface of the condensers for them is 3,458 square feet. There are also four of List and Munn's feed filters on board.

The mean results of the eight hours' full-power trial are set out in the following table:

REPORT OF EIGHT HOURS' FULL-POWER STEAM TRIAL OF H. M. S. "GOOD HOPE" IN THE ENGLISH CHANNEL, FEBRUARY 24, 1902.

	Ford.	*Aft.*
Draught of water, feet and inches	26–1½	26–1½
Steam pressure in boilers, pounds	278	
	Star.	*Port.*
Vacuum, inches	26½	27
Revolutions per minute	123.9	126.1
Mean pressures, high, pounds	106.3	105
intermediate, pounds	44.7	44.63
low, forward, pounds	16.42	16.93
low, aft, pounds	17.43	17.9
Indicated horsepower, high	4,738	4,764
intermediate	5,321	5,399
low, forward	2,573	2,698
low, aft	2,729	2,849
Mean I.H.P.	15,361	15,710
collective I.H.P.	31,071	
air pressure, inch	0.2	
Speed of vessel (mean of five runs), knots	23.05	
Coal consumption per I.H.P. per hour, pounds	1.92	

On this trial five runs were made on the measured course of 23 knots between Rame Head and Dodman Point. The speeds on these successive runs, influenced by tidal conditions, were, respectively, 22.6, 23.71, 22.38, 23.48 and 23.17 knots. The ordinary mean is thus 23.07, and the mean of means 23.05 knots, the closeness of both results proving accurately that the designed speed of 23 knots has been attained. The mean results of these runs are as follows:

MEAN OF FIVE RUNS ON DEEP-SEA COURSE.

	Star.	*Port.*
Mean steam in boilers, pounds	275	
air pressure in stokeholds, inch	.2	
vacuum, inches	26½	27
revolutions	125.1	127.3
Mean pressures in cylinders, high, pounds	107.2	104.3
intermediate, pounds	43.08	43.7
low, forward, pounds	16.34	16.94
low, aft, pounds	17.62	17.88
Indicated horsepower, high	4,823	4,779
intermediate	5,173	5,340
low, forward	2,584	2,726
low, aft	2,786	2,877
Total I.H.P.	15,366	15,722
Gross total I.H.P.	31,088	
Mean speed, knots	23.05	

The power, alike on the thirty hours' trial test at what is known as "continuous-steaming speed," and also on the eight hours' full-speed run, was easily maintained, as already recorded. Following upon the contract trials a series of progressive speed trials were made for the information of the Admiralty, the *Good Hope* being the first of the class to be completed. The higher-speed trials were made on the deep-sea course west of Plymouth Sound, between Rame Head and Dodman Point, where there is sufficient depth of water to obviate any such retardation as was formerly experienced on the measured mile at Stokes Bay with deep-draught vessels running at high speeds. The results of these progressive speed trials are set out in Table I, so far as engine performances are concerned; and here it should be stated that these results refer only to the periods when the vessel was running the stipulated speed test, so that the figures differ slightly from those at the same powers which deal with the thirty-hour and eight-hour run. It will be noticed that all through the trials the intermediate cylinders were developing more than the usual proportion of power. In the case of the high-pressure cylinder, the cut-off at 6,000 indicated horsepower was at .662 of the stroke; at 22,000 indicated horsepower, .662; and at full power, .73—equal to full gear. There is now no re-

TABLE I.—H. M. S. "GOOD HOPE."—PROGRESSIVE-SPEED TRIALS.

.....	Four runs at ten knots in Stokes Bay, February 27, 1902.		Four runs at thirteen knots in Stokes Bay, February 27, 1902.		Four runs at fifteen knots in Stokes Bay, February 27, 1902.		Three runs at eighteen knots on Deep-Sea Course, February 26, 1902.		Three runs at twenty knots on Deep-Sea Course, February 26, 1902.		Four runs at twenty-two knots on Deep-Sea Course, February 21, 1902.		Five runs at twenty-three knots on Deep-Sea Course, February 24 1902.	
Steam in boilers, lbs.	251		250		209		250		250		268		278	
	Star.	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*	*Star.*	*Port.*
Vacuum, inches	23	23½	25	26	25	25½	25½	26½	26	26.4	26½	27½	26½	27
Revolutions per minute	50.9	51	66.2	65.4	77.4	77.5	90	90	99.8	99.8	109 25	108.9	125.1	127.3
Mean pressure, High, lbs.	15 95	15.3	25.02	24.65	34.7	33.25	50	45	66	62.8	94.1	95.2	107.1	104 3
Mean pressure, Intermediate, lbs.	12.75	12.65	17.9	16.42	22.87	22.32	28 46	28.56	34 23	34.23	38.5	38.2	43.08	43.7
Mean pressure, Forward low, lbs.	2.97	3.8	5.05	5.52	6.9	7.37	9.2	9.2	11.26	11 60	12 86	11 8	16.34	16.94
Mean pressure, Aft low, lbs	2.9	3.9	5.05	5.45	6.7	6.85	8.66	9.2	11.26	11.86	13.14	13.2	17 62	17.88
Mean air pressure, inches	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.		.2
Mean I.H.P., High	293	281	596	581	968	923	1,618	1,458	2,368	2,254	3,702	3,727	4,823	4,779
Mean I.H.P., Intermediate	623	620	1,138	1,031	1,699	1,651	2,452	2,464	3,277	3,277	4,935	3,993	5,173	5,340
Mean I.H.P., Forward low	191	244	422	456	673	717	1,044	1,044	1,416	1,459	1,771	1,626	2,584	2,726
Mean I.H.P., Aft low	186	251	422	450	656	666	984	1,044	1 416	1.493	1,807	1,817	2,786	2,877
Mean total I.H.P.	1,893	1,396	2,578	2,518	3,996	3,957	6,098	6,010	8,477	8,483	11,315	11,163	15,366	15,722
Mean collective I.H.P.	2,689		5,096		7,953		12,108		16,960		22,478		31,088	
Mean speed, knots	10.60		13.63		15.91		18.10		20.58		22.09		23.05	
Draught of water	F., 26′. A., 26′.		F., 26′. A., 26′.		F., 26′. A., 26′.		F., 26′. A., 26′.		F., 26′. A., 26′.		F.,26′ 2″. A.,26′ 2″.		F.,26′ 1½″. A.,26′ 1½′.	

The designed draft was 26 feet, at which the displacement is 14,100 tons, so that on all the trials the vessel was at full load and on an even keel.

ducing valve between the boiler and high-pressure cylinder, as in former Belleville-boilered ships.

Table II gives the mean-speed results with the slip of propeller on these progressive-speed runs, and the results are further set out on the diagram, Fig. 1. Little need be said as to the results at 10, 13 and 15 knots. At each speed four runs were made, those at 15 knots being at the top of the tide, and there was little wind or tide to affect the result. Three special runs were made at 18 and 20 knots over the deep-sea course, while the four runs at 22 knots and the five at 23 knots were made during the contract-power trials. Although there are variations in the slip, as

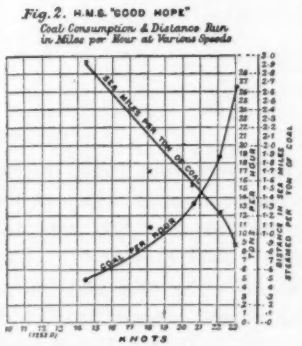
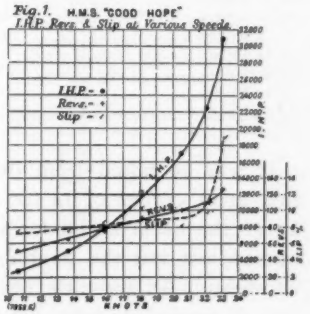


Fig. 2. H.M.S. "GOOD HOPE"
Coal Consumption & Distance Run in Miles per Hour at Various Speeds
SEA MILES RUN PER TON OF COAL
COAL PER HOUR
KNOTS



recorded in Table II, it is a striking fact that the lines which approximately intersect the revolution and slip spots on the diagram advance on a continuous, steady gradient up to 22 knots, so that the variations are probably due to slight inaccuracies in the distance steamed over the course, traceable to the ship "yawing" or to difficulties in seeing the land bearings in the haze. It will be noted that there is a quick rise in slip from 22 to 23 knots. This is probably due to the existence of what may be termed a critical point when this slip begins to increase at an abnormal rate. In torpedo-boat destroyers it is at about 27 knots. It is worth recalling that in the case of the *Diadem* the slip ranged from 16 per cent. at 11 knots to 23 per cent. at 20¾ knots, as compared with from 7 to 18½ per cent. in the *Good Hope*.

Tank experiments have continued steadily since then; trials with propellers on full-sized ships are costly, since twin screws for a ship like the *Good Hope* involve an expenditure of quite £2,000. We understand that the tendency is towards greater surface for a given diameter with a moderate pitch. But after all, it is a question of striking the happy mean between slip and friction.

TABLE II.—MEAN RESULTS OF PROGRESSIVE SPEED TRIALS OF H. M. S. "GOOD HOPE."

——	Revolutions.	I.H.P.	Speed in knots.	Slip per cent.
At 10 knots	51.9	2,689	10.6	7.2
At 13 knots	65.8	5,096	13.63	7.5
At 15 knots	77.5	7,953	15.91	8.4
At 18 knots	90	12,108	18.10	10.2
At 20 knots	99.8	16,960	20.58	8
At 22 knots	109.1	22,467	22.10	9.6
At 23 knots	126.2	31,088	23.05	18.5

It will be noted from our diagram, and from Table II, that this great cruiser of 14,100 tons displacement is driven at 10½ knots, the usual speed for a tramp steamer, for 2,689 indicated horsepower, but the doubling of this power only adds 3 knots to speed. As the rate of progression rises, the addition to energy necessarily increases in much greater proportion. Thus, while the first 10 knots costs only 2,689 indicated horsepower, the second 10 knots costs an addition of 13,000 horsepower. Again, the last mile of the 23 knots speed takes as much power as the first 16 knots—or over 8,600 indicated horsepower—a fact which will bring home to the ordinary reader the great cost of high speeds. Increased power means greater weight in machinery, and this is difficult to get in a warship where gun-power and protection are at least equal in importance with speed. The *Good Hope* excels all other armored warships in speed; but this has required the addition of about 700 tons to the weight of machinery for the last knot. If this were utilized in armor it would cover 6,000 square feet of the side of the ship with 6-inch armor, equal to an increase in the depth of belt of 10 feet for 300 feet of its length. Otherwise it might admit of the ship carrying

several more large guns. The increase in weight of machinery, however, is not nearly so great as would have been the case had not water-tube boilers been adopted, and this point cannot be better enforced than by pointing to the fact that Atlantic liners able to steam 22 knots—and the *Good Hope* can maintain this rate of speed as long as her coals last—have machinery weighing over 4,000 tons, as compared with the 2,500 tons of the *Good Hope*. This cruiser can make a spurt for several hours at 23 knots speed. The 23-knot Atlantic liner is only asked to develop 6 to 7 horsepower per ton of machinery; the cruiser machinery gives 12 to 12½ horsepower per ton.

TABLE III.—COAL AND WATER CONSUMPTION.

——	Tons fuel per hour.	Distance run per ton fuel.	Make-up feed per 1,000 I.H.P per 24 hours.
	tons.	*knots.*	*tons.*
At 6,000 I.H.P. (14.5 knots).....	4.94	2.93	3.43
At 12,000 I.H.P. (18 knots).....	10.65	1.70	...
At 16,900 I.H.P. (20½ knots).....	13.26	1.55	...
At 22,467 I.H.P. (22.10 knots)..	18.61	1.24	4.65
At 31,088 I.H.P. (23.05 knots)..	26.5	.87	4.39

Table III gives the cost of increased power and speed from another standpoint. To drive the *Good Hope* at 14½ knots necessitates the consumption of 4.94 tons of fuel—almost 5 tons—per hour, while at 18 knots it is 10.65 tons; at 22 knots, 18.61 tons; and at full power (23 knots) 26½ tons. But a greater distance being covered per hour, the actual consumption on a voyage of given length does not increase in quite the same proportion. Thus at the low power (14½ knots) one ton of fuel carries the ship nearly 3 miles, whereas at 20 knots it will only drive the ship 1½ miles, at 22 knots for 1¼ miles, and at full power barely nine-tenths of a mile. It can thus be easily understood that the running of a warship at a high speed, without reasonable cause, in times of peace, means a waste of national money. The quarterly trials of all ships at full power for four hours, and at three-quarter power for twenty hours, is probably sufficient for most purposes.

Engine-reversing tests were made during the course of the trials. As with all naval machinery, the main engines are operated by all-round reversing gear, the wormwheel of the gear being graded so as to show the cut-off at different points of the stroke in the cylinders, and each link motion is fitted with an independent gear; but in this case the combined effect of linking up on the main and independent gear is shown on a brass sector at the starting platform, the points of cut-off having been obtained experimentally for the various grades of expansion when using the two together. The results of the reversing trials were as follows:

		Star.	Port.
Steam gear:	Full ahead to stop, seconds, .	10	8
	Stop to full astern, seconds, .	45	45
	Full astern to full ahead, seconds,	35	42
Hand gear:	Full ahead to stop, seconds, .	32	34
	Stop to full astern, seconds, .	53	1 in 35
	Full astern to full ahead, seconds,	46	1 in .05

A special and somewhat severe test was set in connection with the steering machinery, which is the largest yet put in a cruiser. It was fitted by Messrs. Napier Brothers, Limited, Glasgow, who also provided their well-known anchor and capstan gear, and several hoists. The rudder is of the balanced type, of L-shape in elevation, the point of support being at the inside of the right angle. The deadwood is very considerably cut away at both fore and aft ends of the ship, so that there is a greater area of rudder under than beyond the deadwood. This arrangement, which lessens the moment of resistance to rotation, proved highly efficient, as the ship steered splendidly, notwithstanding her great length. The rudder is actuated by a crosshead on the stock with connecting rods to blocks, moved to and fro by a right and left-handed screw rotated by steering engines—all supplied by Messrs. Napier. This arrangement is now most favored for warships because, in the improbable event of any accident disabling the steering engines or shafting, the screw gear is self-holding. Moreover, it occupies little space athwartship, which in the case of a fine-ended cruiser is a great consideration. That in the *Good*

Hope is snugly housed under the protective deck, which is, of course, arched. The test to which the gear was put consisted in driving the ship astern at 18 or 19 knots for half an hour, while the rudder was put alternately 20 degrees to starboard and 20 degrees to port; then 30 degrees to both sides, and finally, hard over, being held at each angle for a considerable period. The gear stood the tests in a most satisfactory manner.

The steering engines (of which there are two) are of the inverted-cylinder type, fitted to the after bulkhead, one in each engine room. The cylinder ports and passages of the steering engines are so constructed as to be self-draining, and asbestos-packed drain cocks are also provided at both ends of the cylinders. The pistons and slide valves are made of solid-steel forgings, and fitted with bronze packing rings, formed with restraining flanges to prevent undue pressure between them and the wall of the cylinder and valve chambers. Each engine works onto a double-throw crankshaft, which is coupled direct to a wormshaft running in large thrust bearings, and working into a gun-metal wormwheel fitted on the end of the steering shaft, and connected to it by means of a pronged clutch. The steering shafts are thus in duplicate, one on the starboard side and the other on the port side of the ship. They are 6½ inches in diameter, and carried under the orlop deck to the steering compartment aft, where they are geared through a train of toothed wheels to the right and left-hand threaded screw working through gun-metal nuts and cast-steel sleeves, and coupled to the cast-steel crosshead on the rudder stock by two massive connecting rods of forged ingot steel. Eight turns of the steering wheels and eight revolutions of the screw shaft traverse the helm through the full angle. A pair of gear wheels are provided for connecting the screw axle to the hand-steering shaft, which is placed on the starboard side and carries four 6-foot 6-inch steering wheels. Twenty-four men can be accommodated at these hand wheels. The gearing is so arranged with clutches that the port and starboard steering engines cannot be connected up at one and the same time, nor can the steam and hand steering gears be coupled up to the steering screw together. A plate

brake is fitted to the crosshead for holding the rudder steady in position while changing from one steering appliance to another. The steering of the ship by the steering engines can be performed from five different positions in the vessel, as well as at the engines, and suitable pedestals and steering wheels are fitted in the forward conning tower, forward and after bridges, orlop deck forward, and steering compartment aft.

The question of temperatures in the machinery compartments becomes of special interest in view of the fact that this is the first ship which has not been fitted with the usual cowls, wind sails being substituted. On the thirty hours' trial at three-fourths power the deck temperature was 50 degrees, and gauges in the double stokeholds recorded from 78 degrees to 80 degrees, and in the engine room 76 degrees, while in the dynamo room, which is abaft the main engine room, it went up to 90 degrees. On the full-power trial readings were taken during each of the eight hours. The deck temperature dropped steadily from 53 degrees to 50 degrees; but down below there was in most parts a steady rise, the readings in the engine room varying between 78 degrees and 84 degrees at one point, and from 82 degrees to 86 degrees at another; but they were not abnormal. In the stokehold the conditions were more decidedly adverse, as is shown in the following table (No. IV). The after stokehold, it may be noted, has a single row of furnaces; hence the cooler atmosphere. Men must frequently go on the double fan flats if the boilers and economizers are to be examined periodically; and although the temperatures given may not seem excessive, the conditions in tropical latitudes will be most uncomfortable, so that any change from the ordinary means of ventilation must be regarded with suspicion.

From first to last the trials were most successful; there was no trouble at any time either with engines or boilers, and thus the program was carried through in an irreducible period of time. The whole performance occupied but ten days, including a Sunday and a day of fog, and pretty rough weather was experienced. Indeed, the speed obtained at full load displacement may be regarded in each case as possible under adverse conditions of

weather; and, given an adequate staff in the engine room, there seems no reason why the *Good Hope* should not repeat her trial performances at any time. Steaming up channel at the end of her deep-sea trials, she made a record passage for warships in traveling, at about 20 knots on a very dirty night, from Plymouth Sound to Spithead in about six hours.

TABLE IV.—STOKEHOLD TEMPERATURES ON FULL-POWER TRIAL.

Hours.	Deck temperature.	Aft.				Forward.			
		Stokehold. 1.	First double fan-flat. 2.	Stokehold. 3.	Second double fan-flat. 4.	Stokehold. 5.	Third double fan-flat. 6.	Stokehold. 7.	Fourth double fan-flat. 8.
	deg.	*deg.*	*deg.*	*deg.*	*deg.*	*deg.*	*deg.*	*deg.*	*deg.*
1	53	102	120	110	124	104	126	108	122
2	53	101	120	108	126	102	124	107	122
3	52	104	134	104	130	106	132	112	128
4	52	107	141	98	146	107	140	119	132
5	52	105	142	100	146	104	140	120	131
6	52	99	145	102	144	101	139	122	132
7	51	92	146	103	145	99	139	123	132
8	50	94	145	102	145	98	139	122	134

—London "Engineering."

Cadmus, Clio.—These two sloops were begun on March 11, at Sheerness. They are of the *Espiegle* class, but slightly larger, displacing 1,096 tons in place of 1,070. They will have the same power—1,400 I.H.P., and same speed, 13.25 knots—as that class.

Gossamer.—This torpedo gunboat, of 735 tons displacement, has had her machinery changed, and has been fitted with water-tube boilers. The power has been increased by 2,500 I.H.P. to 6,000, and the speed by 2 knots, to 21.—"Le Yacht."

King Edward VII.—Little progress has so far been made with the battleship *King Edward VII* at Devonport. The blocks are all ready, and the construction, which has been confined to the top of the slip, is now carried down. Probably in the next few weeks more progress will be made. Hitherto there has been

some doubt as to the exact dimensions of this vessel, but the following are those given out officially:

Length between perpendiculars, 425 feet; breadth, extreme, 78 feet; draught, forward, 26 feet 3 inches; draught, aft, 27 feet 3 inches; displacement, 16,430 tons. First keel plate laid March 8, 1902, by His Majesty King Edward VII.

This ship will therefore be 25 feet longer than the *Queen* and 20 feet more than the *Montague*.

The Admiralty have accepted the tender of Harland & Wolff, Belfast, for the construction of the engines and boilers for the *King Edward VII.* The same firm is making engines and boilers for the battleship *Queen*.

Hyacinth and Minerva.—The cruisers *Hyacinth* and *Minerva*, fitted respectively with water-tube and cylindrical boilers, have continued the series of trials under the supervision of the Special Boiler Committee. Leaving Plymouth Sound together in the morning, they made four runs on the deep-sea course between Rame Head and Dodman Point. The result was given in favor of the *Minerva*, the vessels attaining practically the same speed, with a difference of 657 indicated horsepower to the credit of the *Minerva*. The mean results were: *Minerva*, indicated horsepower, 7,343; speed, 17.671 knots. *Hyacinth*, indicated horsepower, 8,000; speed, 17.669 knots.

The final trial was at full natural draft. The *Hyacinth's* mean speed was 18.59 knots, with 10,170 horsepower, and that of the *Minerva* 18.28 knots, with 8,405 horsepower. The *Minerva* was, therefore, beaten in speed by .31 knot when the *Hyacinth* was doing her utmost, while the former ship had 1,195 horsepower in reserve, which she was not allowed to use. Taking the series of trials carried out during the week, the speed of the *Hyacinth* has not apparently improved since the run to and from Gibraltar last July. As was the case on former trials, the Scotch boilers, as far as can be gathered from the figures obtainable, scored over the Belleville type. It cannot now be said of those in charge of the French boilers that they did not understand them properly, for there is not another ship on which the engine-room staff are so thoroughly acquainted with them as in the case of the *Hyacinth*.

The only difference made in the ships since their last run together is that the propellers of the *Hyacinth* have been pitched higher, and this seems to have had its advantages. In the first trial the Belleville-boilered ship required a considerable excess of horsepower to the *Minerva* to approach anything like the latter's speed. The second trial, at nominally 18 knots, resulted approximately the same; but on the third trial, under full natural draft, the *Minerva's* horsepower was limited to 8,405, while the *Hyacinth* was allowed to go up to 10,170. The result was a slight advantage to the latter ship in speed, but, of course, under the same conditions of horsepower it is evident that the *Minerva* would be the faster ship per horsepower per hour.

Lancaster.—On Saturday, March 22, the first-class cruiser *Lancaster* was launched at Elswick Shipyard by Sir W. G. Armstrong, Whitworth & Company, Limited. The *Lancaster* forms one of ten sister vessels known as the *Monmouth* class. Of these, four—the *Kent*, *Essex*, *Cornwall* and *Suffolk*—are dockyard built, the remainder being built by contract. These are the *Monmouth*, the *Bedford* and the *Donegal*, being built by the Fairfield Company; the *Berwick*, by Beardmore & Company; the *Cumberland*, by the London and Glasgow Shipbuilding Company, Limited; and the *Lancaster*.

She was laid down on March 4, 1901, and therefore slightly more than a year elapsed between her commencement and the launch. Her length is 440 feet, and her beam 66 feet, while her draught forward is 24 feet, and aft 25 feet. Her displacement is 9,800 tons, and her speed 23 knots. Her main armament consists of fourteen 6-inch guns. Two are carried in a twin-hooded barbette on the forecastle, and two, similarly mounted, are placed aft. The remainder are in casemates amidships—six on the main deck, and four on the upper deck. Thus six guns can be fired ahead or astern, and nine on each broadside. There are, beside, ten 12-pounders, three 3-pounders and eight Maxims, distributed over the superstructure. Two submerged torpedo tubes are also fitted. This armament is protected in the main by 4-inch armor casemates, barbettes or hoods, while the bases of the gun positions, the water plane and the funnel uptakes, from the main

deck down to five feet below the water line, are protected by a belt of Armstrong armor varying from 4 inches to 2 inches in thickness. The usual curved protective deck, ¾ inch thick, protects machinery and magazines from shell splinters.

The machinery, which is being constructed by Hawthorn, Leslie & Company, is to develop 22,000 indicated horsepower, and comprises two sets of four-cylinder triple-expansion engines, using steam at 250-pounds pressure. Steam is to be supplied by thirty-one Belleville boilers, which also provide steam for the various auxiliary machines, and there will be economizers. Four sets of dynamos are fitted with direct-acting compound engines for lighting, &c. These dynamos are of the multipolar type, supplying a direct current of 500 ampères at 100 volts pressure. There are also steam steering engines, electric boat hoist, four distilling evaporators, air compressing machinery and ice-making machinery.—London "Engineer."

Leviathan.—The *Leviathan*, one of four of the same class of first-class armored cruisers built by various establishments for the British Admiralty—the *Drake*, at Pembroke Dockyard; the *King Alfred*, at Barrow, and the *Good Hope*, at Fairfield—was launched in September of last year from the shipyard of John Brown & Co., Clydebank, and, having recently arrived at Portsmouth, is to be subjected to her official contract trials on May 5th. Apart altogether from the high speed to be attained by vessels of this class, the trials of the *Leviathan* are likely to prove of considerable interest, as challenging comparison with the results obtained in the case of her sister ship, the *Good Hope*. The *Good Hope*, which, like the *Leviathan*, is of 14,200 tons displacement, with a guaranteed speed of 23 knots, went through her steam trials in a most satisfactory manner in all respects, but it seems that at full power steaming in her case the slip of the propeller was considered somewhat high. In consequence of this, it is believed, a slight modification has been made in the propellers fitted to the *Leviathan*, with the view of ascertaining the effect of coarsening the pitch—the diameter in both cases being the same. The pitch in the case of the *Good Hope* was 22 feet 9½ inches, while in the

case of the *Leviathan* it is 23 feet 9½ inches. Thus equipped, the *Leviathan*, on the thirty hours' trial at one-fifth of the full power, will make runs at full tide over the measured mile at Stokes Bay. On the subsequent trials, with the vessels developing 24,000 and 30,000 horsepower, runs will be made over the 23-mile deep-sea course between Rame Head and Dodman Point, from which will be ascertained her precise speed at the two powers mentioned. As similar runs were made in the case of the Fairfield *Good Hope*, it is thought that interesting results as as to the propeller slip and other things in the two vessels may be obtained.—London "Engineer."[1]

London.—The new first-class battleship *London* has at last completed her trials. On her first thirty hours' run at one-fifth her power the results were as follows: Steam pressure in boilers, 248 pounds; vacuum, starboard, 27.6 inches, port, 27.3 inches; revolutions, starboard, 65.68, port, 65.26; I.H.P., 3,237; speed, 11.5 knots; coal consumption, 1.81 pounds per I.H.P. per hour; draught of water, forward, 26 feet 3 inches, aft, 27 feet. At her thirty hours' runs at four-fifths power, the trial had to be curtailed owing to foggy weather coming on. As the results of these trials are calculated on the mean of the best consecutive twenty-four hours rather than upon the complete run of thirty hours, sufficiently good averages were obtained to allow the trial to be accepted as successful. The ship drew 26 feet 3 inches forward and 27 feet 3 inches aft, and had 262 pounds of steam in her boilers. The vacuum, starboard and port, was 26 inches, and the revolutions were 101.4 starboard and 100.7 port, produced by a mean I.H.P. of 11,718. There was no air pressure, and the speed by patent log was 16.4 knots on a coal consumption of 1.8 pounds per unit of power per hour.

The results of the eight hours' full-power trial were also successful. The limits of the area over which the ship moved were the eastern end of the Isle of Wight and Portland. During the first hour the steam pressure in the boilers was 280 pounds to the square inch, and the air pressure in the stokeholds was 0.1 inch, with an even vacuum of 25 inches port and starboard. The revolutions were 108.6 starboard and 108 port, and the collective I.H.P.

15,442, with a coal consumption of 2 pounds per unit of power per hour. In the second hour the revolutions averaged 109 and the H.P. 15,755, while the coal consumption dropped to 1.75 pounds, and the air pressure in the stokeholds was raised one point, where it remained. At the third hour the steam in the boilers was reduced to 275 pounds and the I.H.P. was 15,210, the coal consumption being 1.88 pounds. During this hour the loss of water was 2½ tons, which fell to 2 tons in the next hour, and then there was no further trouble from this quarter. The steam in the boilers had been reduced to 270 pounds and the revolutions to 107, while the I.H P. came down to 15,076, but the coal consumption went up to 1.96. In the fifth hour all the figures were advanced, the steam in the boilers being 275 pounds, the vacuum 25½ inches, the revolutions 108, the I.H.P. 15,356, and the coal consumption 2.11 pounds. In some respects the same conditions were observed in the sixth hour, but the revolutions came down to 106.4 and the I.H.P. made a small drop to 15,347, and the coal consumption fell to 1.84 pounds. At the seventh hour the steam in boilers dropped to 270 pounds, but the revolutions went up to 107.1 with 15,130 I.H.P., and a coal consumption of 2.1 pounds. In the last hour, with a steam pressure of 275 pounds and 109.1 revolutions, the I.H.P. was 15,160, and the coal consumption 2.1 pounds. The mean I.H.P. for the eight hours was 15,264, and the mean coal consumption 1.97 pounds per unit of power per hour, the mean speed by patent log being a fraction over 18 knots.—Journal "R. U. S. I."

Mars and Hannibal.—The battleships *Mars* and *Hannibal* are being fitted at Portsmouth Dockyard with oil-fuel furnaces for their single-ended cylindrical boilers, of which each vessel has eight. The oil is to be used in its crude state in combination with coal. It was by this process that the best results were obtained recently in the series of trials on the destroyer *Surly*. Oil requires more air for complete combustion than coal, and this is the difficulty with the ordinary marine boiler, so as to avoid the generation of dense smoke. For high power the trials on the *Surly* were not a success, because the amount of oil burned per square foot of grate was about one-half that of the coal consumed;

but in battleships, where the consumption is less than one-third of that of destroyers, the amount of oil to be consumed per cubic foot of furnace will be relatively small.

Medea and Medusa.—The *Medea* has received eight Yarrow boilers and the *Medusa* eight Dürr. Trials between these two ships will shortly be run, under the presidency of the Boiler Committee. If either of these water tubes succeed in getting 19.7 out of the *Medea* class they will do what the old cylindricals have never achieved for them since the preliminary trials. It will also be very difficult for them to beat the normal coal consumption of the class, which has been generally huge. The pity is that, since there are five ships of the class, others were not reboilered also; still, as there is a difference in sheathing, false deductions might have been led to. The *Medea* and *Medusa* are absolutely identical. The odds are all in favor of the *Medea* with the Yarrow boilers. The obscure point lies in the selection of the Dürr, which differs little from the Niclausse. Had the Niclausse been fitted the test would appear to have promised better. Failing the Niclausse, we do not quite see why the Thornycroft—or as the Germans prefer to call it, the Schulz—was not selected. In Germany this boiler has quite ousted the Dürr in general favor, though it may be noted that the latter is still appropriated for some of the new armored cruisers of 9,000 tons or so. For their *Gazelle* class cruisers, which are about the same size as the *Medeas*, the Germans use the Thornycroft type of boiler, which our Committee has altogether ignored. Yet those we have do very well.—London "Engineer."

New Vessels.—The battleships ordered will be the largest in the English Navy, and excel any other vessel of the class, although the United States Navy authorities have now in contemplation vessels which will equal them. Including the one already commenced at Devonport, there will be three built—*King Edward VII*, *Dominion* and *Commonwealth*. Each will absorb some £1,300,000 of the nation's money; and here a note may be made of the steady advance in the cost of our ships of the line. Twenty years ago (1883) half a million was regarded as a fair price; but the old wrought-iron armor cost a little more

than a fifth of the cemented plates of to-day, while armor and guns were not one-fifth so effective. The *Admiral* class of 1889 brought the cost up to £725,000; the *Royal Sovereigns* of 1893–5 made a further increase to £850,000; the *Majestics* of 1895–7 added another £50,000; and then the *Formidables* and *Duncans* of 1901 topped the million, the latter coming near to £1,100,000. It has been a steady progression, and is quite compensated for by the improved fighting qualities, for these latest battleships undoubtedly represent the highest attainments, and form a fit conclusion to Sir William White's work for the Navy; but it must be confessed that while his successor, Mr. Philip Watts, has professional scope equal in range to his high reputation, the patient taxpayer will long for some limit to the opening of the purse string. Three eggs costing collectively four millions sterling are a good lot to put into one basket, even on Easter Monday.

This *King Edward VII* class of battleship is of the following dimensions: Length between perpendiculars, 425 feet; beam, 78 feet; draught, 26 feet 9 inches; displacement, 16,350 tons—the largest ship of the British or any foreign fleet is 15,200 tons. This increase is accounted for by greater offensive and defensive powers. The new ship, in addition to having two 12-inch guns in the forward central barbette, and two similar weapons in the after barbette, will have four 9.2-inch guns, each mounted within a barbette located at each of the corners of the citadel, on either side, but a little abaft, of the central barbettes, so as to enable them to fire ahead and on the broadside with a considerable degree of training abaft the beam. In addition, there will be ten 6-inch guns, all well protected; for, although the barbettes of the 9.2-inch guns are to be only of 4-inch armor, they will be behind the broadside armor, and thus effectually shielded, even from armor-piercing shells. These 9.2-inch guns are a new feature in the secondary armament of the battleships, and as they will be worked, like the 12-inch guns, on mountings of the Vickers' design, for loading in any position, the rapidity of fire will be very great.

In the new American ships eight 8-inch guns are proposed for emplacement in the same quarters as the four 9.2-inch weapons,

but in their case there is the serious objection that the limitation of the space which can be allotted to barbettes, where there are three almost in line athwart the ship, will greatly retard loading operations with two guns mounted within the barbette, so that the rapidity of fire, even from two guns, cannot compensate for the increase in power—19,927 pounds from the 380-pound shot, as against the 13,602 pounds from the 250-pound projectile. In the line of battle, too, energy will be quite as effective as frequency of fire. As to the improved protection, we have already dealt fully with this element, and may here note that the principal change is the increase in the depth of the broadside armor to about 22 feet, instead of 15 feet, as in previous ships, while the thickness is 9 inches on the water line, decreasing to 7 inches at the upper deck, and at the forward end, by gradual stages, to 3 inches—the thickness at the ram. The engines are to develop 18,000 indicated horsepower, to give a speed of 18½ knots. In two of the ships the boilers are to be entirely of the Babcock & Wilcox type; in the third, three-fifths of the power will be got from the same system of steam generators, and the remainder from tank boilers.

It seems probable that such a combination of boilers of the cylindrical and tubulous types will be adopted in the new cruisers just ordered. The view of the Water-Tube Boiler Committee was invited, and we hear that they have suggested such an arrangement; but no decision has yet been arrived at by the Board of Admiralty. These cruisers have already been described in "Engineering;" but it may be said that they are to be named *Devonshire* (the dockyard vessel), *Hampshire*, *Argyll*, *Roxburgh*, *Antrim* and *Carnarvon*. They are similar to, but slightly larger than, the County class, of which ten have been ordered—seven have been launched. Those new vessels form a commendable class; being moderate in size—450 feet long and 10,200 tons displacement; of high speed—23 knots when the engines are developing 22,000 indicated horsepower; with good attacking armament—two 7.5-inch, ten 6-inch and thirteen smaller quick-firing guns; and with a moderate degree of armor protection—a 4-inch belt extending for three-fourths of the length of the ship, and

equal in depth to two decks. The important difference in the later vessels is the substitution of one of the Vickers 7.5-inch guns at bow and stern in place of a couple of 6-inch guns in the same position. The reasons which dictated this change are the same as those to which we have referred in comparing the armament of the *King Edward VII* with that of the proposed United States ships—increased power of the individual gun—11,825 foot-tons for 7.5-inch, against 5,340 foot-tons for the 6-inch gun; and the obviating of placing two weapons in a somewhat confined space.

As to the third-class cruisers, they will prove of special interest, as the vessel to be built at Elswick is to be fitted with Parsons' steam turbine machinery, while that to be constructed at Birkenhead will have the ordinary reciprocating engines, so that here will be provided two vessels of moderate size for comparative trials, which should yield much more reliable data than the small torpedo craft. These two vessels are designed to steam at 21¾ knots. Their displacement is 3,000 tons, with a draught of 14 feet 6 inches, the length of hull between perpendiculars being 360 feet, and the breadth 40 feet. Water-tube boilers of the small-tube design will be fitted. The power to be got per ton of machinery is in the case of the ship with reciprocating engines 18 indicated horsepower, so that the Parsons Company are here pitted against probably the highest convenient attainment in vessels built for sea-going purposes. Of the ten destroyers, one, to be built by Messrs. Hawthorn, Leslie & Co., is to be fitted with the Parsons turbine, so that comparisons can be made in this case also. These destroyers will not differ materially from those already in service, excepting, perhaps, that they will be stronger. On their full-power trial they are to carry a much heavier load of coal and stores, in all 125 tons, and the duration of the run is to be four hours instead of three hours. The speed under these conditions is to average 25½ knots, which is less than in the case of former boats; but as a matter of fact the new vessel, when in the same light trim, should be able almost to equal the 30 knots of the existing boats.—London "Engineering."

New Ships, Contracts for.—The contracts for the armored

cruisers of the *Devonshire* class which have been given out are distributed as follows: One each to the Fairfield Company, of Glasgow; John Brown & Co., of Clydebank; London and Glasgow Company, of Govan; Vickers, Son and Maxim, of Barrow, and Armstrong, Whitworth & Co., of Newcastle. The *Dominion* and the *Commonwealth*, battleships, are to be built by the Thames Ironworks Company, London, and Palmer & Co., of Jarrow. These are the sister ships to the *King Edward VII.* The two third-class cruisers *Amethyst* and *Topaz* are to be built by the firm of William Beardmore & Co., Glasgow.

Prince of Wales.—Twin-screw, first-class barbette battleship; was launched on Tuesday, the 25th of March. The particulars are: Length between perpendiculars, 400 feet; breadth, extreme, 75 feet; draught of water, forward, 26 feet 3 inches, aft, 27 feet 3 inches; displacement, 15,000 tons; engines, inverted, triple-expansion; boilers (Belleville), 20; indicated horsepower of engines, 15,000; speed, knots, 18; maker of engines, Greenock Foundry Co.; coal stowage, 1,920 tons; complement (exclusive of admiral and staff), 781.

Armament.—Four 12-inch breech-loading 50-ton wire guns; twelve 6-inch breech-loading guns; sixteen 12-pounder 12-cwt. guns; six 3-pounder Hotchkiss guns; two 12-pounder 8-cwt.; eight .303-inch Maxims; torpedo tubes (submerged), four; number of torpedoes, eighteen 18-inch, six 14-inch.

Armor.—On sides, 9 inches, 7 inches, 5 inches, and 3 inches; on bulkheads, 12 inches, 10 inches and 9 inches; on barbettes, 12 inches, 8 inches and 6 inches; casemates, 6 inches; fore conning tower, 14 inches; communication tube, 8 inches; after conning tower, 3 inches; communication tube, 3 inches; 12-inch gun shield, 10 inches and 8 inches; roof and floor, 3 inches; protective plating on bows, 2 inches.

Protective Deck Plating.—Main deck, two thicknesses of 1 inch fore end of armor; bulkhead amidships, two thicknesses of ¾ inch forward; middle deck, two thicknesses of ½ inch from armor bulkhead to fore side of barbette, and two thicknesses of 1 inch on slope to lower deck. Slope over main machinery compartment, two thicknesses of 1 inch; lower deck, two thicknesses of

½ inch from slope to stem forward, and two thicknesses of 1 inch and 1½ inches abaft "A" bulkhead.

First keel plate laid, March 20, 1901.

Weight of hull when launched, 5,000 tons.

Belleville Boilers of the Powerful.—The "London Times," that greatest of newspapers, publishes the following from one of its engineering correspondents, which is quite timely and interesting, as it appears to give a faithful account of what the Belleville boilers did on the *Powerful*:

The first-class cruiser *Powerful* is now at Portsmouth dockyard having alterations made that will enable 6-inch quick-firing guns to be substituted for the 4.7-inch guns which were part of her original armament. This has necessitated considerable structural alteration in the way of introducing casemates, etc. The ship being in the reserve, the machinery has been completely overhauled, and occasion has been taken to make more than an ordinarily careful survey of her boilers. It is hardly neccessary to say that these are of the Belleville type, for the *Powerful* and her sister ship, the *Terrible*, the two largest and fullest-powered cruisers that had ever been launched, were also the two first ocean-going vessels in the royal navy to be fitted with the water-tube boiler. In each of these ships there are forty-eight Belleville boilers, which will supply steam for the 25,000 I.H.P. which is needed to drive the 14,000 tons of these 500-feet ships at their top speed of 22 knots.

The boilers of the *Powerful* and *Terrible* have been roundly abused—we have been told that the ships are cripples and can only manage to crawl from port to port—that it is worth while putting on record a few well-authenticated facts about the boilers of one of them. Before, however, speaking more exclusively of the *Powerful*, it is worth while mentioning that on the occasion of one of the parliamentary visits to Portsmouth, some time ago, the chief engineer of the *Terrible* expressed to some members of the House of Commons his strong admiration for the boilers in his ship, and his preference for them over other types of which he had had experience. These included the ordinary return-tube navy boiler. So many "authorities," naval or other, but mostly

anonymous, have been brought forward—or, rather, their statements have been brought forward, the witnesses themselves being judiciously kept in the background—to speak evil of the Belleville that this genuine expression of opinion may perhaps be quoted with advantage. The *Terrible* is now in distant seas, somewhat overdue for home, but her sister ship, is, as stated, at Portsmouth, and any one who can obtain permission from the authorities may examine the state of her boilers for himself.

The *Powerful* was launched in 1895. She was completed and ran her trials toward the end of the following year. The contractors' trials were of a more extended nature than had been usual until a short time previously, and it is well to remember that since the water-tube boiler era the taking-over tests are much more severe than they were in the cylindrical-boiler period. The ship performed well, the horsepower being 25,900, or 900 I.H.P. above the stipulation of the contract. This gave a mean speed of 21.8 knots on a four-hour run. Subsequently serious trouble arose with the crank pin and main bearings. These had to be refitted, and another trial was made at Hong Kong when the ship arrived on the station. The Admiralty then ordered a series of progressive trials to be made, in order to analyze the performance of the ship and her machinery for scientific purposes. At the highest speed run the rate of consumption of coal was just upon 25½ pounds per square foot of grate per hour, the indicated horsepower 21,400 and the speed 20⅛ knots. It is worthy of note that on these trials, during which the coal consumption was carefully recorded, the fuel burnt was under 2.1 pounds per indicated horsepower per hour; in one case, 1.96 pounds, when the ship was logging just on 20 knots. Such an economy would doubtless not be considered a very good result by an engineer of many merchant vessels, especially in cargo boats, in which fuel economy is considered the paramount virtue; but in a fast cruiser, like the *Powerful*, the paramount virtues are of a military nature, and the chief of these is speed. Engineers will understand that all good qualities cannot be combined in one design of engine, and in the navy the big engines needed for top speed prevent the highest economy from being

attained at cruising speeds. Beyond this, in warships there are a large number of auxiliary engines, steam for which is supplied by the main boilers; though the power they exert is not included in the calculation for indicated horsepower. In connection with this matter it may be said that during the commission the amount of steam used for auxiliary purposes has been reduced 50 per cent.

A notable run the *Powerful* made was the trip from Hong Kong to Wei-Hai-Wei, which was made at the rate of over 20⅓ knots over the whole distance. This was in 1899, after the vessel had been on the station nearly two years. For part of this run the engines worked up to over 23,000 I.H.P. The start for the trip was made immediately after the ship had come in from a four-days' passage. Shortly after this the *Powerful* was ordered on special service to the Cape in consequence of the trouble in South Africa. She started from Singapore and ran to the Mauritius at a speed of over 15 knots. At Mauritius she coaled and did the remainder of the voyage at a speed of between 16 and 17 knots, making 400 nautical miles a day. The trip of 4,800 miles was made in thirteen days. On this occasion the engine-room complement was fifty men short, and the coal was of the ordinary description obtained on foreign stations. The performance of the *Powerful* since her arrival at the Cape will be within the recollection of all, and the efficient state in which her machinery was found to be when a sudden call was made upon it enabled her to render material aid at a time of national emergency.

The boilers must be credited with a part of this good result. Care and watchfulness are more essential to water-tube boilers than anything else. It is the same thing through the whole range of engineering practice; one cannot get higher efficiencies without paying for them in some way. That is a duty that has to be faced. The boilers that are in the ship now are those that were originally placed in her. With the exception of a few tubes, there have been no renewals. So far as the boilers are concerned, the *Powerful* would be ready to go to sea again to-morrow. A number of tubes in various parts of the different boilers have been taken out and cut open longitudinally, in order

to examine their condition more closely and test the thickness of metal, to discover if there had been waste by burning. The results were quite satisfactory, the gauge having been well preserved. All the covers to the junction-boxes have also been removed and every tube has been thoroughly examined. The deposit was slight, and there has been found no trace of pitting, a trouble that has attacked some other Belleville boilers, more especially in the economizer tubes. The much-talked-of corrosion of boiler tubes has not been present in this earliest of water-tube boiler ships.

The *Powerful* has not been fortunate all through, even in her boiler department. One tube was burnt and gave way when the vessel was new, owing to the admission of salt water into the boiler through the opening of a wrong valve by mistake. The element was taken out and the tube renewed, after which the element, having been cleaned, was put back. During the commission two tubes split. This was due to the leaking of a condenser and the consequent admission of salt water to the boilers. This illustrates the weakness of the water-tube boiler; it must have good fresh water to feed it. The same thing may be said in a lesser degree of the multi-tubular shell boiler working at high pressures. There is, however, this difference in favor of the pipe boiler. If a tube becomes encrusted and bursts it is certainly a serious matter, but if a furnace top gets over-heated and comes down the danger is infinitely greater. Moreover, a damaged furnace puts the boiler out of action until the ship gets to a dockyard or large engineering establishment, whilst a split tube can be renewed in a few hours at sea. The water-tube boiler, however, has this serious objection. It contains so little water that the admission of no great quantity of salt water forms a large proportion of the whole contents, and the engineer is less likely to make the discovery before the damage is done.

These are, again, conditions that must be faced. It is an old tale retold. When steam was first generated for power purposes it was made in a simple pot like a kettle or saucepan. Then an internal flue was introduced, and complication began. No doubt the engineers of those days—who were the prototypes of

the give-me-the-good-old-tank boiler school of the present day —said very much the same things as are being said now about the water-tube boiler. Then complication was carried a big step further by the invention of the multi-tube boiler, which has held its own for about half a century; and, if we may believe some authorities, will hold its own to the end of time.

Whatever may have been the results with the Belleville boilers of other ships—and they have been often far from successful—the experience with the *Powerful* shows that, with proper care and when properly constructed, these boilers can be made to last a considerable period, and the estimate of Sir John Durston of a life of one commission would appear to have been a very moderate one indeed. No doubt there are now better water-tube boilers than those of the Belleville type, but, at any rate, it does not always deserve the sweeping condemnations of its most hostile critics. At the time it was put in the *Powerful* it was the only water-tube boiler of which there was experience in ocean-going vessels.

Queen.—On March 7th was launched at Devonport the battleship *Queen*, a ship which is the embodiment of the latest developments in the design and construction of warships. The *Queen* is, to all intents, a ship of the *London* class; but being later, embodies certain improvements. These may be tabulated as follows:—(1) Limitation of ventilating cowls, which are now recognized as "shell-traps." (2) Substitution of an open for a closed 12-pounder battery amidships. (3) Substitution of stockless anchors for the old type anchor. In all other particulars data that apply to this ship apply with equal force to the *London* class. Particulars of the vessel are as follows:—

Displacement, 15,000 tons; length (between perpendiculars), 400 feet; beam, 75 feet; draught (extreme), 29 feet; guns: four 12-inch wire wound, 50 tons; twelve 6-inch 45 caliber Vicker's; sixteen 12-pounders, 12 cwt.; two 12-pounders, 8 cwt. (boat guns); six 3-pounders, eight Maxims; torpedo tubes: four 18-inch submerged.

The armor consists of a Krupp cemented belt 15 feet wide, extending from the after bulkhead to the bow. It is 9 inches

thick amidships, thins to 6 inches just by the fore barbette, and thence reduces to 2 inches at the extreme bow. It is 4 inches thick at 30 feet from the stem, and here the belt proper ends. The continuation is 2 inch nickel steel, and is carried down over the ram point, thus giving great rigidity to a weapon that no warship is likely to use. Aft of the after bulkhead, up to the level of the lower deck, there is 1 inch nickel laid on the ½ inch skin plating, constituting a complete belt against small projectiles —three-pounders and the like. This protection is what has been termed "naval architect's armor"—that is to say, it has probably no practical value. Those who saw the *Belleisle* after her first battering will remember how the 12 inch armor amidships on that ship is holed in places like a honeycomb where three-pounders have hit and buried themselves in it. They did not penetrate, it is true, but they went in a good deal further than the value of the 1 inch, or, for that matter, 2 inches of steel.

There are two armor decks. The upper one is flat, 1 inch thick of steel where the side armor is thickest, and 2 inches elsewhere. This armor deck runs along level with the top of the belt, and forms the main deck of the ship. Its object is to prevent shell bursting on the main deck inflicting damage below that level.

The second deck is the ordinary inclined deck reinforcing the belt. It springs from the lower edge of the belt amidships, and going up at a sharp angle, has a flat top about the lower deck level in the middle of the ship. Forward and aft it sinks more, and has less curve. This particular deck is common to all our warships, from the *Majestic* class onward. The recent *Belleisle* experiments would seem to indicate that it is decidedly inferior to the French system of a flat deck below the belt, and there are grave doubts as to its efficacy, or rather as to whether the theoretical protection afforded is correct. In theory, 2 inches inclined equal 4 inches vertical armor. In practice, a shot falls obliquely, and so reinforces indirectly the side armor.

In theory, a 9-inch belt like the *Queen's*, reinforced by a 2-inch belt, is worth as follows: 9 inch cemented Krupp $\times$ 3 = 27

inches of wrought iron; 2 inches deck × 2 inches for inclination × 2½ inches for material = 10 inches wrought iron. Total resisting value is, therefore, in theory, 37 inches of wrought iron plus the coal, which may be called another 3 inches; grand total 40 inches. Practical value is probably nearer 30 inches, even allowing for the damage inflicted on the projectile by getting through the hard face of the outer plate. In battle, however, the ship will rarely present herself at anything but an angle to the hostile gun; this will render capped projectiles useless and increase the difficulties of others, from which it may be inferred that a 9-inch Krupp belt will keep out everything save the lucky shot at near range.

To resume. The barbettes of the *Queen* are 12 inches thick, non-cemented Krupp, equivalent in value to Harvey nickel. The turrets are Harvey nickel, 8 inches thick, inclined at an angle of about 35 degrees. Turrets of this form, we may observe, are general in every navy except the French, where the big ships adhere to vertical turrets. So far as we know, it has never occured to any one to submit these two rival systems to an experiment as to their relative values. Since, however, anything that hit a turret would send bolts and rivets flying inside, penetration may be of no importance, and the thickness or otherwise of the armor or its inclination alike immaterial. These turrets are avowedly for protection against small guns, and though the gun mountings of to-day embody all that human ingenuity can devise against the effect of shot, it is hardly conceivable that either guns or guns' crews will survive the fearful impact of a big projectile striking with an energy of at least 20,000 foot-tons, and possibly 30,000 to 40,000. The result seems bound to be something like hitting a clock with a hammer.

The *Queen's* secondary guns are in Krupp non-cemented casemates, 6 inches in front and 2½ inches in rear. They are situated like those of the *London*, in four rough groups of three, two on the main deck and one above between them, exposing its base to shell attack. This arrangement is supposed to lead to less "interference" than when the upper casemate is immediately above the other, as in cruisers. It is, however, a remarkable

fact that all our battleships adhere to one system and all our cruisers to another. The *Drake* and *Canopus* have identical protection, so it would certainly be interesting to know why their casemates differ. Amongst naval officers there is a very strong feeling against the battleship disposition of casemates.

The machinery of the *Queen* is two sets of vertical triple-expansion engines, actuating twin screws turning inward. They are designed for 15,000 indicated horsepower, which is to give 18 knots, and 110 revolutions. Steam is supplied by fifteen Babcock & Wilcox boilers. The coal supply is 900 tons normally, and 2,100 tons maximum capacity.

Arcs of fire are: Big guns, about 130 degrees either side of the axial line; end-on casemates, 130 degrees from the axial line; other casemates, about 55 degrees before and abaft the beam. The armor weighs about 3,000 tons; the weight of hull, including armor, &c., is 9,985 tons. The 12-pounders are mounted, four on the main deck in the extreme bow, four distributed on the same deck aft, eight on the upper deck firing over the low bulwarks, two—the 8-cwt. "boat guns"—on the top side of the fore conning tower.

A proposal is afoot to replace some or all of the *Queen's* 6-inch guns by 7.5 pieces, and, in view of the present trend towards arming our ships as well as any possible enemies, this may very probably be attempted.

A 7.5-inch gun with mountings weighs approximately 27 tons, and its charge and projectile 256 pounds. With the new propellant some weight will be saved, and approximately 10 rounds go to the ton, and about 20 tons of ammunition are carried per gun at 200 rounds the gun. That is 240 tons for 12 guns, which, plus the weight of 12 guns and mounting—324 tons—comes to about 564 tons for an entire armament of 7.5-inch guns. To this we may add 75 tons for increased size of casemates, giving a grand total of 639 tons, which we may call 650 in round numbers. The 6-inch 45-caliber Vickers with its mounting, etc., weighs 9¼ tons. Weight for twelve guns is therefore 111 tons, against 324 tons. Ammunition runs at about 18 rounds to the ton; the total for all the secondary guns at 200 rounds we can put at

132 tons, giving a grand total of 143 tons for the present 6-inch armament, against 564 tons as an outside weight for one of 7.5-inch guns. The extra weight would then be about 421 tons.

Now, 50 tons, more or less, is a negligible weight in any of Sir William White's battleships—the margin in them being about 800 to 1,000 tons in 15,000. By this we mean that all of them carry maximum coal without their speed being affected. To reduce the coal would not be politic, perhaps, but the extra 420 tons odd would not very appreciably affect the speed of the *Queen*, while in any case she would consume coal enough to soon cover the difference. But the weight can be saved far more cheaply. The exact weight of "stores" carried is hard to get at, but since in dealing with a 15,000-ton total small fractions do not matter, we can arrive at an approximation sufficiently near. Something over two tons a day in the way of food, &c., are daily consumed by a battleship's crew. Much of it is in the way of food that is replenished weekly; but stores for six months are carried. If we assume these at a ton a day, we shall not probably be much more than a hundredweight or so out, and the total cannot be less than 200 tons. Probably, seeing that it includes many things beside food, 300 tons or more would be nearer the mark. Since a ship must coal at least once a month, a good three-quarters of these stores are deadweight of no value, and here alone nearly 200 tons could be saved.

Then, again, the 7.5-inch could do with less than 200 rounds. Fifty tons could be saved here. About fifty to a hundred tons of spare gear is quite unnecessary, and thus, without touching the coal, the extra 420–50 tons of 7.5-inch armament is sufficiently nearly covered to ensure no appreciable loss of speed. In addition, the 12-inch guns—each round for which weighs nearly half a ton—carry far more rounds than they could conceivably require. The *Queen* could not well mount more 6-inch guns than she does—save by substituting a battery *a la Mikasa*—for the main-deck casemates, and that means a heavy increase in weight. Four 7.5-inch could replace four 6-inch at a cost of 160 tons, on which 10 tons of ammunition at least could be saved, and that extra 150 tons—which might conceivably be consider-

ably less, for we have taken outside weights for the extra size of casemates—could be carried without the ship feeling it.

Our own impression is that, even did it necessitate reducing the coal supply by 400 tons, the change in armament would be a gain, for the burst of these 200-pound shells from the 7.5-inch gun is prodigious, while probable enemies all carry armor that the 7.5-inch could tackle where the 6-inch could not. There is a great deal of 5-inch armor on foreign ships, and the 7.5-inch in battle conditions should be superior to that armor, and go through it whenever it hit it seven times out of ten, while a 200-pound projectile at 2,500 foot-seconds initial velocity is going to hit hard enough to make itself extremely unpleasant, even where it does not get through. Reflecting on this and kindred things, we strongly advise the Admiralty to take the bull by the horns and give the *Queen* the projected 7.5-inch guns. It is a thing that can be done, for it is worth it. The 6-inch gun is either too small or too large for modern requirements, and only the fact that it is the smallest gun that can be trusted to fire lyddite that will detonate with certainty justifies its use at all. Two 4.7-inch would weigh no more, and do equal execution, save with lyddite, and shoot more truly at sea. They also threaten to land us in the *reductio ad absurdum* for the 4-inch may be better still, and so on, till we get to the 3-pounder, the most deadly gun of any, if only its range were longer. Going upwards from the 6-inch, the 9.2-inch is barred from much employment on the score of weight, but the 7.5-inch is not, and we do not think there can be much question that a fire of six 7.5's from the *Queen's* broadside would match even the two 9.2's and five 6-inch of the *King Edward*. This six 6-inch would certainly fail to do.—"London Engineer."

Russell.—H. M. Battleship *Russell*, built and engined by Palmers' Shipbuilding and Iron Company, Limited, Jarrow, recently went through her official trials in a very successful manner, the trials following one another without hitch. On Friday, April 25th, the eight hours' official speed trial at full power was successfully undergone. On April 18th, under 3,768 indicated horsepower, the *Russell* made 12.1 knots per hour on a

coal consumption of 2.4 pounds. In her thirty hours' continuous-steaming trial she developed a speed of 17.95 knots per hour, at 13,696 indicated horsepower, and a coal consumption of 2.14 pounds; while in her official full-power trial she attained 19.4 knots per hour, her engines working up to 18,229 indicated horse power, with a coal consumption of 2.09 pounds.

Success.—The *Success*, torpedo-boat destroyer, built and engined by Messrs. Doxford & Sons, Sunderland, has carried out her three hours' 30-knot full-power trial quite satisfactorily. She had 254 pounds of steam in her boilers, and a mean air pressure of 5.7 inches. The indicated horsepower was 6,597, and the mean of six runs over the measured mile showed a speed of 29.908 knots, while the mean speed of the three hours was 30.023 knots.

Turbine-driven Vessels.—The Admiralty have given orders for the construction on the Tyne of another turbine-driven torpedo-boat destroyer. In this connection it may be interesting to note the launch, on 11th February by Messrs. Hawthorn, Leslie & Co., at their Hebburn Yard, of a new destroyer named the *Velox*, whose machinery is supplied by the Parsons Marine Steam Turbine Company at Wallsend-on-Tyne. The new vessel, which is generally of the same type as the unfortunate *Viper* and *Cobra*, has not been built to the order of any government. She is 210 feet long, 21 feet wide, and 12 feet 6 inches molded depth Special attention has been paid to the conditions necessary to secure longitudinal strength. The main propelling machinery consists of two independent sets of Parsons turbine engines, one high-pressure engine and one low-pressure engine being on each side of the vessel. This gives four turbines, each of which has its own line of shafting, and, as each shaft carries two propellers, there are eight propellers in all. The high-pressure turbines drive the outer shafts and the low-pressure turbines the inner ones. For going astern reversing turbines are incorporated in the exhaust casing of each of the low-pressure cylinders. A novel feature in this vessel is the introduction of ordinary reciprocating engines fitted in conjunc-

tion with steam turbines. These engines are of the triple-compound type, and are coupled direct to the main turbines and work in conjunction with them. They take steam directly from the boilers, and exhaust through the high-pressure turbine, the exhaust from the latter passing in turn through the low-pressure turbine, and thence to the condensers. These reciprocating engines are for use at cruising speeds, when low power only is needed, and are therefore of comparatively small size.

All steam engines, including the steam turbine, do not show high efficiency when they are working much below the power for which they are designed, and as destroyers very seldom run at their top speed, they are apt to be wasteful of fuel during the greater part of their steaming. The new arrangement which Mr. Parsons has introduced should therefore be a distinct advantage. When higher powers than those needed for absolute cruising speeds, under ordinary conditions, are needed, steam will be admitted to the turbines direct from the boilers, and when the highest speed is needed, which would bring the rate of revolution beyond that permissible with reciprocating engines, steam will be entirely cut off from the latter, they being at the same time thrown out of gear, and the steam turbines alone would be used. With this arrangement the *Velox* will doubtless prove an exceptionally economical destroyer at cruising speeds.

The boilers are of the Yarrow type, and have been made by Messrs. Hawthorn. The trials of this vessel will be looked forward to with great interest.—Journal "R. U. S. I."

FRANCE.

The French Navy in 1901.—Following our usual custom, we give here particulars of the past twelve months in the French Navy. For data we are chiefly indebted to "Le Yacht."

The principal event, in French eyes, at any rate, has been in connection with submarines. Outside the famous milk experiments solid progress seems to have been made, the most noteworthy being the reduction of time in submerging to about one-third of what it originally was. For the rest, sham attacks have

been very plentiful, and these, though as yet hardly simulating real war, are appreciably nearer to it than a year ago.

The French naval maneuvers were tactically and strategically almost impossible to follow; full stops being apparently made now and again in order to allow of submarines testing *la gloire*. On the other hand, the French seem to have freed themselves from the shackles of the one idea that permeates our naval maneuvers, and nonsense about fleets $A_1 + A_2$ are $> B_1 + B_2$ and $< B_1 + B_2 + B_3$ was reduced to a minimum. Practical objects were sought. These were:—(a) rapid victualling, coaling, &c.; (b) wireless telegraphy.

In the first valuable experience was gained and things worked well; the second was rather a failure, the French system proving inferior to Marconi, just as ours did the year before. Successful trials have been run by the *Requin*, *Iéna* (18 knots), and *Montcalm* (21 knots). Failures were recorded for the *Jeanne d'Arc* in boilers, while the excellent results obtained by the *Chateaurenault* were marred by failures in the engines, which could not use all the steam supplied by the boilers.

The following vessels have been entered into service: *Torpilleurs de haute mer Trombe*, *Siroco*, *Audacieux*, *Mistral*, *Simoun*, all of from 26 to 28 knots, and all armored boats; two 30-knot boats, *Boree* and *Tramontane;* several second-class boats of 25 knots; two destroyers, *Pique* and *Epee*, and the submarines *Francais* and *Algerien*. Other submarines, *Farfadet* and *Lutin*, have done trials; also four *submersibles*, *Sirene*, *Triton*, *Espadon* and *Silure*.

One large ship only has been launched—the *Leon Gambetta*, armored cruiser—which was fully described in "The Engineer" in the early half of 1901.

Reports of work at the different yards, &c., are as follows:

Le Havre (Normand).—Torpedo boats *Siroco*, *Mistral*, *Rafaele* and *Bourrasque* delivered or sent on trial.

Le Havre (Forges et Chantiers).—*Simoun* and *Typhon*, torpedo boats, delivered; the turbine boat *Libellule* still under construction.

Cherbourg.—Battleship *Henry IV* completed externally, and

expected to be completed during 1902; armored cruiser *Jules Ferry* laid down; coast-defense battleship *Requin* reconstructed; coast-defense battleship *Furieux* in hand for reconstruction. A special submarine station has been established here, with four boats in commission and four on trials.

Brest.—*Leon Gambetta*, armored cruiser, launched; work upon armored cruiser *Marseillaise* (launched 1900), battleship *Suffren* (launched 1899); completion of the *Iéna* (launched 1898); preparation for laying down the first-class battleship *Republique;* under reconstruction, *Devastation;* awaiting reconstruction, *Neptune.*

Lorient.—Work upon the armored cruiser *Gloire*, afloat; building of the *Conde.* Work upon *Jurien de la Graviere* and *Gueydon.*

Nantes.—*St. Nazaire* (Chantiers de la Loire).—Work upon armored cruisers *Desaix* (launched 1900) and *Aube* (building). Construction of picket boats, &c.

Rochefort.—Armored cruiser *Dupleix* completing; completion of destroyer *Pertuisane;* work in connection with destroyers *Escopette, Flamberge, Rapiere, Carabine, Sarbacane, Francisque* and *Sabre*; work upon submarines *Gnome, Farfadet, Lutin* and *Korrigan*, all of which are somewhat delayed.

Bordeaux.—Armored cruiser *Kleber* in hand, greatly delayed. Several torpedo boats, including two *torpilleurs de haute mer, Boree* and *Tramontaine*, launched and sent to Rochefort for completion.

Toulon.—Completing afloat armored cruiser *Dupetit Thouars*, trials of which are expected to begin about October next; big armored cruiser *Victor Hugo* laid down at Mourillon; work upon the *Jeanne d'Arc*, the boilers of which have completely given out. Several submarines building.

La Seyne.—Armored cruiser *Sully* on the stocks; *Montcalm* on trials; work upon the *Chateaurenault.*

The ships ordered during the past twelve months were:

In State dockyards: *Republique, Victor Hugo*, two destroyers, twenty-two submarines. By contract: *Patrie*—battleship—*Victor Hugo*, several destroyers, eleven torpedo boats. Eight destroyers in hand at Government yards, sixteen at contractors'.

The new submarines are to be named *Naiade*, *Frotee*, *Perle*, *Esturgeon*, *Bonite*, *Thon*, *Souffleur*, *Dorade*, *Lynx*, *Ludion*, *Loutre*, *Castor*, *Phoque*, *Otarie*, *Meduse*, *Oursin*, *Grondin*, *Anquille*, *Alose* and *Truite*. Three experimental boats, *Q 35*, *Q 36* and *Q 37*, of large sizes, and not yet named.

During 1901 few accidents occurred. On January 3d, 1901, the torpedo boat *Fleurus* was run into at 8 A. M. by a tug in a fog. She was hit on the port side aft, and sustained damage to the extent of two holes, 6 feet and 15 feet long respectively She had to be beached to keep her afloat. The damage was well aft. On March 12th, 1901, torpedo boat *No. 91* struck a rock, and sank suddenly while making her way back to harbor. On February 12th, 1901, torpedo boat *No. 245* had an accident to a boiler, injuring three men, off Toulon. On May 31st, 1901, an above-water torpedo from the *St. Louis* hit the torpedo boat *Cyclone*, which was towing a target for her. The torpedo deviated after striking the water. Observing this, the *Cyclone* increased speed, but the torpedo struck and penetrated her amidships. The torpedo was destroyed.—London "Engineer."

Building in 1902.—It is reported that the naval construction to be undertaken by the French in the present year includes the commencement of the building of one ironclad, two armored cruisers, two torpedo catchers, and sixteen torpedo boats; also the ordering of three ironclads and thirteen submarine vessels, making a total of thirty-seven vessels.

Amiral-Aube.—This first-class armored cruiser is a sister ship to the *Condé*, recently launched at Lorient, and is the last of the five armored cruisers laid down in accordance with the 1896 program of construction, the other three, which are of the same class, being the *Sully*, *Gloire* and *Marseillaise*. They are improved *Montcalms*, a little larger, with somewhat better protection for the guns. The *Montcalm* class carry their guns in casemates with unprotected bases, while the *Condé* and her sisters carry their guns partly in casemates which have their bases protected, and partly in closed turrets. Her displacement is 10,014 tons; length, 452 feet; beam, 66 feet. Her engines are of 20,500 H.P., driving three propellers, and her estimated speed

is 21 knots. She can carry 1,500 tons of coal, giving a radius of action, at 10 knots, of 10,400 miles, and, at full speed, of 1,940 miles. Her armament comprises two 194-mm. (7.6-inch), eight 164-mm. (6.4-inch), six 100-mm. (3.9-inch), eighteen 47-mm. (1.8-inch) and four 37-mm. (1.4-inch) guns, and she has five torpedo tubes, two of which are to be submerged. Her complement is fixed at 25 officers and 590 men, and her total cost is 24,985,682 francs (£999,427). She is to be completed by June, 1903.—Journal "R. U. S. I."

Bourrasque and Rafale.—Twin-screw torpedo boats.—These two boats, recently delivered at Cherbourg to the French Government by MM. Augustin Normand and Co., of Havre, are of the *Cyclone* unprotected class. The dimensions are: Length on load line, 147 feet 6 inches; extreme breadth, 16 feet 7 inches. The weights carried on trial, exclusive of chains, anchors, masts, boats, &c., and comprising only torpedoes and torpedo tubes, compressing pump, artillery and ammunition, provision water for boilers and crew, coals necessary for steaming 1,020 nautical miles at 14 knots (as determined by an eight hours' preliminary trial), crew and effects, provisions, including 4 tons 2 cwt. for sundries, amounted to 34.5 English tons in the *Bourrasque* and 39 2 tons in the *Rafale*, the displacement tons being respectively 153.3 and 158 English tons. The full-speed trials, which took place after the ordinary preliminary runs on the measured mile, were of four hours' duration, one hour of which was to be run at 25 knots minimum, one hour at maximum speed, and the next two hours at 25 knots. The one hour maximum speed was 31.53 knots for the *Bourrasque* and 31.41 knots for the *Rafale*, the mean of the three other hours being 25.79 and 26.20 knots respectively. The boilers are of the Normand type, the engines being, as usual, fitted with feed heaters, cylinder safety valves, water filters, &c.—London "Engineering."

Condé.—The new first-class armored cruiser *Condé* has been launched. Her dimensions are as follows: Displacement, 10,014; beam, 66 feet; length, 452 feet; 20,500-H.P.; speed, 21 knots. She has water-tube boilers and three propellers; she carries 1,600 tons of coal, giving a radius of action

at 10 knots of 10,400 miles, and at full speed of 1,940 miles. She has a steel armored belt and armored deck of 5.9 inches and 1.6 inches respectively, and the turrets are protected with 150-mm. (5.9-inch) armor. The armament consists of two 194-mm. (7.6-inch), eight 164-mm. (6.4 inch), six 100 mm. (3.9-inch), eighteen 47-mm. (1.8-inch), four 37-mm. (1.4-inch) guns, and there are five torpedo discharges, two of which are submerged. The complement will comprise 25 officers and 590 men. She is to be completed by the end of 1904. The ship will take the water 55 per cent. completed, her twenty-eight Niclausse boilers are almost all in place, and the fixing of her screw shafts is completed. Her place on the slip is to be taken by *C.14*, one of the large armored cruisers of the *Léon Gambetta* class, and the two principal officials of the Construction Department, who are to superintend her building, have been sent to Brest to make themselves acquainted with the methods being followed in the *Léon Gambetta*. —Journal "R. U. S. I."

Chateaurenault.—The new first-class cruiser *Chateaurenault* has commenced her official trials. During a six hours' run, the engines developing 18,400 I.H.P., a mean speed of 21.9 knots was obtained with a coal consumption of 643 gr. per H.P. per hour. During a twenty-four hours' run, the engines under natural draft developed 14,800 I.H.P., the side engines making 114 revolutions and the central, 110; for two hours the ship was run at full speed, the engines making 129 revolutions and developing 22,500 I.H.P., speed not given. The engines are reported to have worked well, although a tube in one of the boilers burnt; towards the end of the fourth hour there was some diminution in the resistance of the central engine, which is attributed to the breaking of one of the blades of the screw.

Courbet.—The *Courbet*, if her laying down be accepted as a criterion, is a contemporary of our *Inflexible*, for she was laid down at Toulon so long ago as 1876. She was, however, no less than six years on the stocks, her launch not taking place till 1882, while her completion for sea was nearly parallel with that of our *Admiral* class.

In design she approximates closely our *Alexandra*, though

always superior to that ship. In 1898–99 she was taken in hand for reconstruction and from then till last year was reboilering, rearming and reconstructing generally.

The result of these modifications can be best appreciated from the following table. In order to emphasize the meaning of the change, we have placed after each gun its war-game notation, as an index to its penetrative abilities :

.....	Old *Courbet.*	New *Courbet.*
Displacement, tons...	10,200 (nominal).....	10,800.
Guns in battery	Four 12.6-in. (B).....	Four 10.8-in. (A).
bow.....	One 10.8-in. (C).....	One 6.4-in. (D).
stern.....	One 10.8-in. (C).....	One 9.6-in. (B).
over battery.....	Two 10.8-in. (C).....	Two 9.6-in. (B).
upper deck.....	Six 5.5-in. (E), two 3-pdrs., twenty 1-pdrs.	Ten 4-in. (E), fourteen 3-pdrs., seventeen 1-pdrs.
Torpedo tubes...	Five above water.....	Five above water.
Broadside fire.....	Two 12.6-in. (B), three 10.8-in. (C), three 5.5-in (E), one 3-pdr., ten 1-pdrs.	Two 10.8-in. (A), two 9.6-in. (B), five 4-in. (E), seven 3-pdrs., nine 1-pdrs.
Bow fire.....	Two 12.6-in. (B), three 10.8-in. (C).	Two 10.8-in. (A), two 9.6-in. (B), one 6.4 in. (D).
Stern fire.....	Two 12.6-in. (B), three 10.8-in. (C).	Two 10.8.in. (A), three 9.6-in. (B).
Engines	Compound vertical 3-cyl ..	Same as before.
Boilers.....	Cylindrical	Belleville.
I.H.P.....	8,100	8,500.
Speed	15.1 knots.....	15.3 knots.

It will be seen how great an increase has been made in the penetrative power of the guns, and this, since the new fire far more quickly than the old, without any loss of shell power.

Nothing of note has been done to the *Courbet's* armor, which is still her weak point. The belt is from 15 inches to 8¾ inches of iron, with a 3½-inch compound deck on top of it. This deck is composed of a 2-inch iron deck with a 1½-inch steel deck laid over it.

The redoubt is 9½-inch iron, with, as in all old ships, huge ports. To lessen the danger of these ports 4½-inch hardened-steel shields have been fitted to the 10.8-inch guns. Whether these fulfil any useful purpose is a moot point; probably not, for the gap still exists. In addition, the 9½-inch iron armor is to be penetrated by an 8-inch gun, so the central battery's chances of

survival are not brilliant. Still, since from an old ship of no value at all the French have evolved a vessel more than equal to our *Admiral* class, they may certainly claim to have accomplished something worth the doing, and as our *Admiral* class are still officially rated as first-class battleships, the *Courbet* may at least claim the same rank.

The dimensions of the *Courbet* are 318 feet 4 inches long on the water line, 69 feet beam, and about 28 feet draught—possibly rather more. She carries 900 tons of coal.

It may be added that some uncertainty exists as to whether 13.4-inch or 12.6-inch pieces constituted her old main armament. The difference, however, was immaterial, both pieces being on about a par with our 38-ton muzzle loader. All the new pieces are guns of the latest model, 45 calibers long.—London "Engineer."

Dupleix.—The new first-class armored cruiser *Dupleix* has been commissioned for her trials. She is the first to be ready of three vessels of a similar type, the other two being the *Desaix*, under construction at Saint-Nazaire, and the *Kléber* at Bordeaux; all three vessels are intended for service on foreign stations. "They are really rather large '*Dupuy de Lomes*,'" says the "Yacht," "but they do not show any remarkable advance on that ship, which was launched more than twelve years ago. The principal advantage they seem to possess over their prototye is that they ought to be more habitable in hot climates. Nevertheless, we may ask whether it is still not possible to give them a more powerful armament. They have a displacement of 7,700 tons, as against 6,250 of the *Dupuy de Lome*, but their armor protection is very little better; their speed should be 21 knots, but the *Dupuy de Lome* with her new boilers will probably equal that; their coal supply is 1,200 tons, the *Dupuy de Lome* can carry as much. The *Dupleix* carries ten 16.4-centimeter (6.4-inch) Q F. guns, the *Dupuy de Lome* carries six 16.4-centimeter guns and two 19.4-centimeter (7.6-inch) guns, the former's guns being the more powerful, as they are of the latest model; on the other hand, the *Dupuy de Lome* only cost 10,500,000 francs, as against 16,308,847 francs for the *Dupleix*, and the

largely increased cost of the latter is hardly compensated for by the very slight superiority she possesses."—Journal "R. U. S. I."

Guichen.—This vessel has made her coal-consumption and speed-endurance trials with satisfactory results. For the last three hours of the trials she maintained a speed of twenty-two knots.

Henri IV.—The new second-class battleship *Henri IV* has at last been commissioned for her trials; she was laid down more than four and a-half years ago, and launched in August, 1899. She is a low free-board ship, with, however, a long, high forecastle for steaming against a head sea, and as the French naval authorities hope that she may prove the forerunner of a useful type, it may be as well again to briefly recapitulate her principal characteristics. Length, 354 feet (over all), 325 feet between the perpendiculars; beam, 73 feet; displacement, 8,948 tons, with a maximum draught of 23 feet. The peculiar feature of the ship, new so far in the French Navy, although it is to be found in our own *Inflexible*, *Colossus*, *Edinburgh*, etc., is that the sides directly they leave the immediate bow no longer follow the water line, but a straight line fore-and-aft inboard, forming a narrow superstructure as compared with the full beam of the ship. From where the forecastle ceases the freeboard of the *Henri IV* is very small, especially aft, where it is only 4 feet out of the water. Protection is afforded by a complete water-line belt of hard steel except for a few feet right aft, where a bulkhead athwartship takes the place of the side armor, following the sharp V-shape of the stern; the thickness of the belt tapers from 11.8 inches amidships to 7 inches at the extremities, and is 7 feet deep, reaching 3 feet below and 4 feet above the water. Above the water-line belt is another of 4-inch armor extending from the stem to some 30 feet abaft the central line of the ship, while above this belt again amidships is a central redoubt protected by 4-inch steel armor, in which four of the guns of the secondary armament are mounted; while the turrets for the heavy guns, one forward and one aft, are protected by 9.5-inch steel armor, the bases by 12-inch, and the supporting tubes, which extend to the belt, 9.5-inch. The armored deck is 2.2 inches thick, and there is a

curved 1-inch armored deck below this again. The armament consists of two 27.4-cm. (10.8-inch) guns, one in each turret, with 11.8-inch steel hoods, and seven 13.8-cm. (5.5-inch) Q.F. guns, of which four are mounted in the lower redoubt, two immediately above, protected by shields, one each side, and the seventh in a small turret aft on the upper deck; twelve 3-pounders are also distributed over the superstructure. All the turrets and ammunition hoists can be worked by hand or electricity.

The engines, to develop 12,000 I.H.P., are expected to give a speed of 17 knots, the boilers being Niclausse water-tube. The normal coal supply will be 725 tons, but, if necessary, 1,100 can be carried, which will give the ship a radius of action of 7,500 miles at 10 knots speed.—Journal "R. U. S. I."

Jeanne d'Arc.—This armored cruiser was laid down in 1895, and, as has been noted in the JOURNAL, has been very unfortunate in her trials due to serious trouble with her boilers.

Her principal characteristics are: Length, 475.7 feet; beam, 63.65 feet; mean draught, 24.67 feet; coal at this draught, 1,400 tons; displacement, 11,300 tons.

The armament consists of two 19-centimeter guns in turrets, forward and aft; eight 14-centimeter rapid fire, ten of 100-millimeter rapid fire, sixteen of 47 and eight of 37-millimeter rapid fire, with two 450-millimeter torpedo tubes.

There are three main engines placed amidships between the two groups of boilers. These boilers are forty-eight in number, of the Guyot-Du Temple small-tube type, with a total grate surface of 1,636 square feet; the boilers are divided into two groups, each group being divided up among four fire rooms.

During the recent firing trials of this vessel the results obtained were very poor, as, on account of the excessive vibrations of the hull, it is impossible to sight the heavy guns.

Jules Michelet.—A new armored cruiser of this name will soon be put on the stocks at Lorient. Some of her principal characteristics will be: Length, 480.65 feet; displacement, 12,550 tons; speed, 22 knots. She will carry four guns of 194 millimeters, in turrets, twelve of 164.7 millimeters, rapid fire, also mounted in pairs in turrets, and four guns of 164.7 millimeters,

mounted in an armored casemate. She will also carry twenty-two 47-millimeter rapid-fire guns.

Jurien de la Gravière.—As her boilers are of the small-tube Du Temple-Guyot type, which have given such trouble in the *Jeanne d'Arc*, some fears are expressed as to the results of the ship's forthcoming trials, but, as some important modifications have been introduced, notably the fitting of automatic feed-supply regulators, it is hoped they will pass off satisfactorily.

Montcalm.—The new first-class armored cruiser *Montcalm* has made another satisfactory twenty-four hours' trial; with the engines making 115.5 revolutions a mean speed of 18 knots was maintained.

No. 223.—This small torpedo boat of 84 tons displacement, 121 feet in length, was launched on March 12. She is one of six boats of this class being built in Government yards.

Renan and Michelet.—The two new French armored cruisers are to be called *Ernest Renan* and *Michelet*. They are of the *Gambetta* class. The improved *Gambettas*, the *Lamartine* class of 23½ knots, seem to be dropped for the present.

Requin.—A distinct point of difference between the French and British navies is the way in which the former rebuild and modernize old ships till they become equivalent to new vessels. Thus the old *Requin* had no fighting value at all, the reconstructed ship is fully equal, if not superior, to the *Jemmappes* and *Valmy*. Whereas two years ago the French navy counted but four coast-defense ships of any utility, it will, two years hence, have added five more at no great cost—the four *Requins* and the *Furieux*, with which we shall be dealing on some other occasion. How complete the reconstruction has been can be gauged from the table on the next page.

This, however, by no means tells all the tale, for in the untreated ship all the belt was below the water. Now 2½ feet of it stands above the water line—a difference of some importance in a ship intended to fight only in smooth water. This is stated to be the result of lightening the ship by 600 tons odd.

The belt, which is of compound armor, is 20 inches thick amidships, tapering to 11½ inches at the ends, and thinning also

as it descends. The total depth of the belt is 7½ feet. A flat 4-inch steel deck is laid on the top of it.

.....	Old *Requin.*	New *Requin.*
Actual displacement, tons.	7,600	7,000.
Main artillery	Two 75-ton, 16.5-in.	Two 10-in.
Armor on it	17¾-in. compound	10-in. Harvey nickel.
Armor at base	Small 8-in. hoist only	10-in. Harvey nickel.
Minor artillery	Four 4-in., sixteen 1-pdrs.	Six 4-in., ten 3-pdrs., four 1-pdrs.
Torpedo tubes	Two above water	None.
I.H.P.	6,000	6,230.*
Maximum speed, knots	14.5	15.1.*
Boilers	Twelve cylindrical	Twelve Niclausse.
Coal (normal), tons.	400.	400.
(maximum), tons.	800.	800.
Armor belt, compound	20-in., 11¾-in.	20-in.. 11¾ in.
Conning tower	3-in.	12-in.

* With ten boilers only.

The lower-deck side is unarmored. Forward and aft rise the turrets, each containing a single 10.8-inch 45-caliber gun of the latest pattern. These guns roughly weigh half what the old guns did. They are in closed turrets, revolving on circular fixed bases of 10-inch Harvey nickel, all the machinery being inside these. The guns are electrically maneuvered. Their penetration and range are, of course, in excess of the old 75-ton pieces, the respective ballistics being:

	75-ton 16.5 inches.	10.8 inches.
Length in calibers, ...	19	45
Initial velocity, foot-seconds, . .	1,662	2,625
Initial energy, foot-tons, . . .	17,000	22,750
Weight of shell, pounds, . . .	1,720	476

Shot for shot, the old guns were infinitely more serious in their shell power, but the rate of fire was very slow indeed, while the high trajectory made hitting anything problematical. The new guns fire fairly rapidly and very accurate, the trajectory being very flat; their "danger space" is, of course, much larger. For one hit the old guns could have secured under battle conditions the new may expect to score ten or twelve—possibly more.

The old barbettes were very large and thick, though they gave

the gun no more protection than do those of our *Admiral* class. These ships, indeed, are nothing but larger copies of the *Requin* class, as originally built, with more gun power, and all the armor gone from the ends. They could, perhaps, by virtue of superior gun power, beat a non-reconstructed *Requin*, but matched against the *Requin* "*transform*," there can be little question as to their inferiority. As the *Admiral* class still form the bulk of our Home Service Fleet, and the *Requin* will be in reserve for the French Channel Fleet, the matter is one of considerable interest both sides of the Channel, and we cannot but pay a tribute of admiration to the resolution with which the French Ministry of Marine either rebuilds old ships or sends them to the scrap heap. What the French would do had they the misfortune to possess the *Admiral* class we can hardly venture to say. A Frenchman, asked about the matter, replied that it was "impossible to conceive of France building such ships" —which was a happy retort, but little else. Probably the French would no more have attempted reconstruction than our Admiralty—despite the advice of Lord Brassey—seem inclined to. On the other hand, they would never have retained them as units of their fleet—they would have sold them as old iron, built a cruiser out of the proceeds, and reckoned the bargain advantageous.

It is worthy to note that, in reconstructing the *Requin*, the French substituted for the two above-water tubes a couple of extra 4-inch guns on the topside—probably a wise step, for under modern fire, men are hardly likely to be left standing at unprotected above-water tubes till torpedo range is reached.

Most of the superfluous wood work has been taken out of the *Requin* during reconstruction. The appearance of the old *Requin*, *Indomitable*, &c., is familiar enough, with the two pairs of funnels in line abreast. These are still retained in the *Indomitable*, but the *Requin*, having changed her boilers to Niclausse, has had new funnels placed, and bears now very little resemblance to the familiar form. In these days of funnels a hundred feet high the stumpy funnels of the *Requin* are very noticeable. Of course, the lower the funnel the less the target, but this point seems

lost sight of or disregarded in the enthusiasm for improved draft. Indeed, high funnels seem regarded as a necessity in all water-tube boilered ships. As the *Requin*, with only ten of her twelve Niclausses alight, more than exceeded the contract indicated horsepower and speed, her short funnels seem to have been no inconvenience. Other things being equal, the boiler that can do with the minimum of target in the way of funnels is the boiler that all naval men will swear by.—London "Engineer."

GERMANY.

The German Navy in 1901.—We give below a short account of the progress of the German Navy during the last twelve months.

During 1901 the cruiser *Niobe*, of the *Gazelle* class, has entered into service. Trials have been carried through with the *Barbarossa*, battleship of the *Kaiser* class. She made 18 knots with 13,940 indicated horsepower, which is 940 excess horsepower and half a knot over contract speed. The *Freya* has done her trials, and reached 18.5 knots with 10,330 indicated horsepower; this is a knot under the contract speed, with 330 excess horsepower. She belongs to the *Hertha* class, none of which seem very special steamers. The *Amazone* and *Medusa*, of the *Niobe* class, are on trials still; their sisters *Ariadne* and *Thetis* reached indicated horsepower, 8,827 and 22.18 knots, and 8,888 and 21.75 knots respectively. The contract is indicated horsepower 8,100 and 22 knots speed for these later *Gazelle* type, which seem more successful than some of the earlier ones. All have excellent engine room, and all the machinery is easily got at. Launches include four battleships of the *Wittlesbach* class—*Schwaben*, *Mecklenburg*, *Zaehringen* and *Wettin;* one armored cruiser, *Prinz Adelbert*, recently described in "The Engineer;" one gunboat, *Panther*, and eight destroyers.

The work done at the various yards is as follows:

Imperial yards: Wilhelmshaven.—Battleship *Schwaben*, launched August 19, 1901. Work afloat upon the *Wittlesbach* (launched 1900). Repairs of the *Kaiser Friedrich III*, after accident.

Kiel.—Launch *Prinz Adalbert*, armored cruiser, June 23, 1901. Work afloat upon *Prinz Heinrich* (launched 1900). *Heimdall* and *Hildebrand* reconstructed. Heavy repairs to *Kaiser Wilhelm II.*

Dantzig.—Launch of gunboat *Jaguar*, April 1, 1901. Completion of *Freya* and *Thetis*. *Beowulf* reconstructed.

Private yards: Vulcan Company, Stettin.—Launch of *Mecklenburg*, November 9, 1901. Completion of Russian cruiser *Bogatyr* (launched 1901).

Germania: Kiel.—Launch *Zaeringen*, June 12, 1901, and destroyer *G. 108*. Building of new 13,000-ton battleship *H.* Completion of *Amazone*, fourth-class cruiser. Construction of destroyers *G. 109, 110, 111, 112, 113.*

Schichau (Dantzig).—Launched battleship *Wettin*, June 6, 1901; laid down new 13,000-ton battleship *H.*

Schichau (Elbing).—Launched destroyers *S. 102, 103, 104, 105, 106* and *107;* completion of Russian cruiser *Novik.*

Weser (Bremen).—Building 2,715-ton cruisers *G* and *H*—improved *Gazelle* class; completion of work on *Medusa* and *Ariadne*—*Gazelle* class.

Howalt (Kiel).—Building of 2,715-ton cruiser *J.*—improved *Gazelle.*

Considerable works have been undertaken at all the Imperial yards, especially at Dantzig.

During 1901 disaster has been rather plentiful with the German fleet. The old torpedo gunboat *Wacht* has been totally lost by collision with the *Sachsen* during the maneuvers. In January, 1901, the destroyer *VI* grounded badly near Kiel, but eventually was got off little damaged. The principal disaster was to the *Kaiser Friedrich III*, battleship, which, on the night of April 1, 1901, ran at full speed on to a reef near Adlergrund, east of Arcona. She passed over, but filled four compartments and damaged her rudder. The accident set her liquid fuel on fire. This liquid fuel, "masut," was in the double bottom, cut off from the ship. The shock of grounding opened seams and forced some of it into the boiler room, where it took fire. It took three hours to subdue the fire, which damaged eight boilers.

The flooded compartments are reported to have bulged, and at one time the abandonment of the ship was considered. Officially the disaster was minimized as far as possible, but there is little doubt that these are the actual facts. The cost of repairs was originally set down at over £150,000. An official statement said: "The cost will be much less than the amount first estimated."

At the same time as the *Kaiser Friedrich III* the *Kaiser Wilhelm II* also touched bottom, destroyed her shoe and badly injured her propellers; but, as she was able to take the *Kaiser Friedrich III* in tow, it would appear that her injuries were considerably less than those of the flagship, and she was at no time in danger of capsizing. These accidents were caused by defective charts, which showed less than five fathoms as seven to eight fathoms. A lightship near the spot was also found to be moored 750 yards away from where she ought to have been.

In conclusion, mention may be made of some long-distance sea trials. In April the *Freya* ran for five consecutive days at a mean of 16 knots. The extreme designed speed is 19.5 knots, but she never reached this by a knot. In January the *Nymphe* attempted a similar trial, but at the close of the third day she ran into a fog. Her results were: Draught, forward, 14⅝ feet; aft, 16⅝ feet; air pressure, 0.7 inch; revolutions (mean), 144; indicated horsepower (mean), 5,624; average speed, 19 knots; coal consumption, 2.08 pounds. This is a most remarkable result. A similar trial of the *Niobe* the year before, with 140 revolutions, and indicated horsepower 4,921, mean, gave 19.45 speed, and coal consumption 2.01—again a remarkable result. The consumption, it will be noted, is high in both cases.—London "Engineer."

Frauenlob.—The German fourth-class cruiser *G* has been launched and christened *Frauenlob*. She is a slightly enlarged and improved *Gazelle*. Two sister ships are on the stocks.

Her principal characteristics are: Length between perpendiculars, 328.1 feet; beam, 38.71 feet; mean draught, 16.07 feet; displacement, 2,650 tons.

The hull is built without double bottoms and is divided into

15 watertight compartments, with a protective deck from 37 to 50 mm. in thickness.

She has two 4-cylinder, vertical, inverted, triple-expansion engines, steam for which is furnished by water-tube boilers. The I.H.P. is to be 6,000 at natural and 8,000 at forced draft, giving a speed of 21.5 knots.

The normal coal supply is 500 tons, giving a cruising radius at economical speed of 5,000 miles. The total amount that can be carried is 700 tons.

H.—This small protected cruiser, 2,715 tons displacement, 8,000 H.P., and 22 knots speed, was launched April 22.

Kaiser Karl der Grosse.—This battleship made her trials in February and passed successfully. The results were as follows: Forced-draft trial, 13,833 I.H.P., 116 revolutions; air pressure at W.T. boilers, 1.5 inches; at cylindrical boilers, .5 inch; speed, 18 knots.

The principal data of this vessel are: Length, 377 feet; beam, 66.9 feet; draught, mean, 25.7 feet; displacement, 11,081 tons; engines, number and type, three 4-cylinder triple-expansion; diameter of H.P. cylinder, 31.9 inches; diameter of I.P. cylinder, 51.2 inches; diameter of L.P. cylinder (two), 55 inches; stroke, 37.4 inches; arrangement of cylinders from forward, L., H., I., L.

There are four boiler compartments. In each of the after two compartments are three single-ended 3-furnace Scotch boilers. Total grate surface, 432.75 square feet. Total heating surface, 14,726.5 square feet.

In each of the forward two compartments are two Schultz boilers, one single and one double-ended. Total grate surface, 465.05 square feet; total heating surface, 23,381.6 square feet.

Both boiler systems work at a pressure of 200 pounds per square inch.

There are three 3-bladed propellers; the wing propellers are 14 feet 5.2 inches in diameter, the center screw 14 inches in diameter. The pitch of the screws varies from 16.6 feet to 19.9 feet, and was set at 19.7 feet during the trials. The projected surface of each of the wing screws is 49 square feet, that of the center screw 47.5 square feet.

Prince Henry.—The large armored cruiser *Prince Henry* has made her first trial trips, but has not yet reached the expected maximum speed. The pitch of the propellers is being changed.

With a displacement of 8,800 tons, and 15,000 I.H.P., she is to make 20½ knots, while the *Furst Bismarck* can only make 19 knots. The new large armored cruisers *Ersatz*, *Konig Wilhelm* and *Prince Adalbert* are to have 9,093 tons displacement, and their triple engines are to develop 15,200 I.H.P., giving a speed of 21 knots.

No. 107.—The Schichau destroyer *No. 107* of the German Navy, on trials made 28.4 knots in place of the 27 knots contract speed.

No. 108.—This torpedo boat had its trials on March 23. The maximum speed attained was 28.8 knots, the mean being 28.5 knots, exceeding the designed speed by a knot.

HOLLAND.

Submarine.—The commission charged with the investigation of the subject of submarine boats has decided to purchase a boat of the *Holland* type.

ITALY.

Italia.—The Italian warship *Italia*, which was to have been given water-tube boilers, is not now to be fitted with them. She used to have eight cylindrical and sixteen locomotive; her new boilers will be one-third locomotive and two-thirds cylindrical. The old 100-ton guns are to be retained. To replace them with 10-inch guns would have entailed very great expense, and, after all, there is a certain trend of feeling towards the big gun just now. Wherever a ton shell gets inside a ship it must do incalculable mischief; it is likely to be a knock-out blow. Given four great guns, one of them may be expected to hit before the lot are out of action, and one hit will suffice. An old ship, no matter how modern her artillery, is not going to last long. There is a great deal, therefore, to be said for giving her a weapon that must render her value doubtful, and that may make her terribly dangerous. The moral effect of a 100-ton gun that may not hit, but will annihilate if it does hit, is probably much greater than

that of a smaller piece certain to hit, but equally certain not to annihilate. So much is said against the big gun now-a-days that it is well to remember that all the arguments in favor of it are not yet dead.—London "Engineer."

JAPAN.

Asashio.—The *Asashio*, destroyer, built by Messrs. J. I. Thornycroft and Co., for the Imperial Japanese Navy, has had a successful trial. The speed attained as a mean of six runs on the measured mile was 31.057 knots. The mean revolutions of the main engines were 381.4, and the horsepower 7,224. The mean speed for the three hours' run was 31.038. The order for the *Asashio* and a sister boat, named the *Shirakumo*, was placed with the Company on November 16, 1900, and the first boat hoisted the Japanese flag on February 20, 1902. This second boat, which has now completed her trials, is in an advanced state, and will be handed over shortly.

Torpedo-Boat Destroyers for the Japanese Navy.—The following facts are of interest as showing with what certainty anticipated results are now secured when the necessary experience has been acquired. Time was when many runs had to be made and costly experiments undertaken with propellers, and alterations in the trim of a boat, in grates, in fans, in methods of firing, before the promised speeds were reached. Here we see that in the present day the torpedo destroyer can be turned out with as much certainty as a tramp steamer. The list refers to torpedo-boat destroyers built for the Imperial Japanese Navy by Yarrow & Co., Limited, Poplar:

Name.	Date of Launch.	Date of Official Trial.	Speed in Knots.
Ikadsuchi,	Nov. 15, 1898	Dec. 23, 1898	31.32
Inadsuma,	Jan. 28, 1899	Mar. 8, 1899	31.037
Akebono,	Apr. 25, 1899	May 4, 1899	31.08
Sazanami,	July 8, 1899	July 20, 1899	31.382
Oboro,	Oct. 5, 1899	Oct. 14, 1899	31.262
Niji,	Dec. 16, 1899	Dec. 21, 1899	31.156
Akatsuki,	Nov. 13, 1901	Nov. 21, 1901	31.121
Kasumi,	Jan. 23, 1902	Jan. 29, 1902	31.245

The trial in each case consisted of a continuous run of three hours' duration, carrying a load of 35 tons in the case of the first six and 40 tons in the case of the last two destroyers.

As an example of promptitude with which experienced firms can carry out special work, we call attention to the fact that on Thursday, January 23d, Yarrow & Co., of Poplar, launched a Japanese torpedo-boat destroyer. She had her preliminary trial on Friday, January 24th, and the official trial took place on Wednesday, January 29th, with the following results.

The official trial consisted of a three-hours' continuous run with a load of 40 tons on board, the speed being ascertained by six runs at the Maplin measured mile. The following is a record of the six measured-mile run:

Run.	Hour.	Air pressure in stokehold.	Revolutions per minute.	Time.	Speed.	First mean.	Second mean.	Admiralty mean.
	A. M.	*inch.*		*m. s.*				
1	11·13	.6	395.8	2 4	29.032			
2	11·24	.93	392.1	1 49.4	32.906	30.969		
						30.795	30.882	
3	11·33	.9	390.3	2 5.5	28.685		30.941	31.075 knots on measured mile.
4	11·43	1.1	396.8	1 47.5	33.488	31.087	31.161	
						31.236		
5	11·54	1.1	398.1	2 4.2	28.985		31.315	
	P. M.					31.394		
6	12·03	1.2	401.7	1 46.5	33.802			

After the six runs were made, to ascertain the advance per revolution of the screw, a three-hours' trial was proceeded with, with the result that a mean speed, during the three hours, of 31.245 knots was obtained.—London "Engineer."

Shirakumo.—The *Shirakumo* belongs to the Japanese Navy, and well illustrates the determination of the Japanese Admiralty that in point of quality of material their naval forces shall be at least on a par with those of any other power. The boat and

engines were both built by Messrs. John I. Thornycroft & Co., Limited, of the well-known Chiswick yard. On the trials, which were made in boisterous weather, the mean speed on a three-hour run amounted to 31.030 knots, and during six runs on the measured mile a mean speed of 31.819 knots was registered, whilst the engines indicated an average of 7,648 horsepower. These engines are of the triple-expansion, four-cylinder type. The high-pressure cylinder is 22 inches in diameter, the intermediate cylinder 29½ inches in diameter, whilst the two low-pressure cylinders each measure 31 inches in diameter; and the stroke is 19 inches. The boilers are the latest development of the Daring type, and maintained steam with ease throughout the runs, during which the steam pressure averaged 231 pounds per square inch, and the air pressure in the stokeholds 3.12 inches of water. The engines ran at a speed of just over 400 revolutions per minute, and worked most smoothly throughout the trials.—London "Engineering."

NORWAY.

Submarine.—The Norwegian Government is contemplating the construction of a submarine boat, for which purpose a Norwegian naval officer has visited several countries. In all probability the boat will be built at the Horten shipyard, Norway, a foreign syndicate finding drawings and an engineer, against a remuneration of £10,000 for the first and £5,000 for each subsequent boat. The cost of the boat is calculated at some £27,000, and it will take about a year to build.

RUSSIA.

The Russian Navy in 1901.—During 1901 there have been laid down by Russia one battleship, *Slava;* one other, unnamed; four protected cruisers—*Kagul, Otchakoff, Oleg* and one unnamed; four *Noviks—Kalgoula, Olmaz, Jenitchug* and *Izumrud;* five 250-ton destroyers; five 150-ton torpedo boats, and a sea-going collier of 7,200 tons, *Kamtschatka.* Abroad there have been ordered one *Novik* at Schichau's, Danzig, and a 12,000-ton engineering-school transport, *Okean,* at Kiel. Plans have been

prepared for five new battleshigs of 20-knot speed, and five destroyers of 30 knots. Three *Borodino* class battleships have been launched—*Borodino* and *Alexander III* in Russia, *Tsarevitch* in France. Other launches are: *Bogatyr* at Stettin, the *Boyarin* at Copenhagen, three destroyers—two of them in France—four torpedo boats, and one small gunboat for the Caspian. Trials have been run with the *Retvisan*, in the United States, 18.8 knots being secured, 0.8 in excess of contract. At home, *Pobieda*, 18.5 knots—0.5 in excess of contract, without the armor on—*Diana* and *Pallada*. Also *Askold* and *Novik*, in Germany, and the destroyers *Gagara*, *Woron*, *Philin*, *Sowa*, *Forel*, *Sterliad*, *Oseteyr*, *Lossos*, *Kephal*, *Yastreb*, *Nyrok*, *Pavlin*, *Pelikan*, *Phasan* and *Albatross*—total 15. Some torpedo boats and submarines have also done trials.

All the fifteen destroyers are in commission or waiting for it; the *Retvisan* and *Variag*, have also been taken into the service from Cramps, at Philadelphia. Details of general work at the home yards are as follows:

New Admiralty.—Launched *Borodino*. Laid down *Slava*, *Kamtschatka*, and a cruiser of the *Bogatyr* type. Building *Boutakoff*.

Galernii Ostrov.—Work upon *Diana* and *Aurora*. Building *Orel*, battleship.

Baltic Works.—Launched *Alexander III*. Laid down *Almaz*. Building *Suvaroff*.

Nevsky.—Laid down *Jemtchug* and *Izumrud*.

Kronstadt.—Reconstruction of *Minin*, for training-ship duties, and *Pamiat Azova*, cruiser. Completion of *Peresviet*. Completion work on *Osliabia* and *Pobieda*, *Pallada*, *Diana* and *Aurora*. All these ships on trials also.

Nikolaieff.—Laid down *Kalgoula*—*Novik* type; unnamed battleship of 12,000 tons odd, sister to *Kniaz Potemkin Tavritchesky*; *Kagul*, cruiser.

Sevastopol.—Laid down and building *Otchakoff*, cruiser. Completion and trials of *Kniaz Potemkin Tavritchesky*. General refit of Black Sea fleet, and reboilering with Bellevilles of the old battleship *Ekaterina II*.

A certain number of disasters have marked the year. The *Peresviet* has been ashore, but was got off unhurt. A big fire destroyed the cruiser *Vitiaz*, building at Galernii Ostrov, and damaged the *Aurora* of the *Pallada* class. It may be of interest to note that *Vitiaz* seems a singularly unlucky ship name in the Russian Navy. By some curious coincidence every *Vitiaz* has come to a sudden end, the predecessor of the ship burned at Galernii having been lost with most of her crew off Vladivostock some five or six years ago.

It is impossible to give any trustworthy information concerning Russian submarines. A large number are undoubtedly built or building, and one seems to be of very large dimensions —perhaps an attempt to evolve a sea-going submarine. It can, however, be only an experimental vessel. As an instance of the mystery attending Russian submarine construction, we may draw attention to the fact that while "All the World's Fighting Ships" states "fifty building or to be built," the "Naval Annual" gives none at all. The truth probably lies in a mean between these two extremes, and the fifty can be nothing but a vague "projection." Since, however, it has yet to be demonstrated that the submarine is of any more practical utility than the Brennan torpedo or observation mines—if as much—the matter is, perhaps, of rather academical interest as yet. Alexander the Great seems to have been the first person to interest himself in submarine navigation. That was a good two thousand years ago. Russia has not been "at it" ever since then, it is true, but her interest in the matter seems to have begun in the days of Catharine the Second—say a good hundred and fifty odd years ago, and in the last fifty years countless submarines have been experimentally constructed on the Neva. The importance of present work depends, therefore, on the question whether it is definite or merely experimental construction. The Russian 30-knot boat that can stay five days under water—vague accounts of which appeared in some of our daily contemporaries a few months ago—is probably of the same type as the sea serpent and the big gooseberry.

In personnel great increases are being made in the Russian

Navy, and a markedly increased attention to gunnery is reported. It is stated that the Barr and Stroud apparatus has been adopted this year; but whether this is the range-finder or the transmitter, or both, is not very clear.

The naval maneuvers were dealt with in the "Engineer" in the autumn of last year, and need not be recapitulated here.

The bulk of the Russian fleet is in the far East, the *Peresviet*, *Gromovoi* and *Variak* being the latest recruits. It is officially stated that the *Sissoi Veliky*, *Dmitri Donskoi*, *Vladimir Monomach* will come home this spring, to be replaced by the *Retvisan*, *Askold* and *Bogatyr*. The *Bayan* will replace the *Rurik* later on in the present year.—London "Engineer," February 14, 1902.

Bogatyr.—It is announced from the Vulcan Works at Stettin that the preliminary trial of the second-class cruiser *Bogatyr*, of 6,500 tons, held in December, in the presence of Russian officers, gave most excellent results. At forced draft the engines developed 20,500 I.H.P., the speed attained exceeding 24 knots. She was taken back to the yard for completion, and the official trial of her will be held shortly.

Ekaterina II and Chesma.—The repairs to the battleship *Ekaterina II*, which were carried out at Nicolaieff, included the substitution of Belleville boilers for her old cylindrical ones, and are now almost completed. Her sister ship, the *Chesma*, will next be taken in hand, and will receive triple-expansion engines and water-tube boilers, by which change it is hoped that her speed will be materially increased.

Kniaz Potemkin Tavricheski.—A trial has taken place of the engines of the battleship *Kniaz Potemkin Tavricheski*, of 10,600 horsepower. The results were successful; these engines were turned out by the Nicolaiev Works, and are the first of the kind produced in the south of Russia.

Lossos.—This destroyer, of 312 tons, 5,700 I.H.P., and 26 knots, was launched at Havre on March 11.

Okean.—The Russian engineering-school transport *Okean*, of 12,000 tons and 18 knots speed, has been launched at Howalt's yard, Kiel. Her bunkers carry 4,000 tons of coal, from which it would appear that she is a species of fleet collier. The speed

is to be 18 knots. She is fitted with six Belleville, six Niclausse, one Yarrow and two Thornycroft boilers.

Diana.—A trial of the engines of the first-class crusier *Diana* at full power has been made, lasting six hours without a break, with a view to her official taking over. Her draught proved to be 20 feet 10 inches on an even keel, which corresponds to a displacement of 6,660 tons, or 70 more than the estimate. The engines worked on the whole satisfactorily and without heating of the bearings, but during the second hour the port engine came to grief slightly, so that the trial was stopped, but the damage was repaired by the firm in 2½ hours.

A second six hours' trial was completely satisfactory, and seven series of diagrams were taken, which showed the engines had together developed 519 more H.P. than contracted for. The following is the analysis:

Port engine, with 170.6 pounds pressure and 103.3 revolutions, I.H.P., 3,972.

Starbord engine, with 159 pounds pressure and 130.8 revolutions, I.H.P., 3,948.

Midships engine, with 131.9 revolutions and 172 pounds pressure, I.H.P., 4,209.

Total for all three engines, 12,129 H.P.—Journal "R. U. S. I."

Filine.—From the Neva Works another torpedo-boat destroyer, the *Filine*, has also undergone her trial at forced draft. She is the third vessel built by them on the lines of the *Sokol*. A commission was on board her to decide whether she should be taken over. The result of four runs at forced draft was to show a mean speed of 26.94 knots. The engines, fed with steam at a pressure of 190 pounds, gave an average of 397 revolutions.

The vessel was tried for four hours uninterruptedly at nine-tenths of the maximum draft, or 262 revolutions, and the engines were worked quite regularly without heating of the bearing parts. Three trips on the mile at this draft gave an average speed of 24.57 knots. Further trials will have to be put off till next year, owing to the lateness of the season.—Journal "R. U. S. I."

Gagara.—The torpedo-boat destroyer *Gagara*, built on the

lines of the *Sokol*, at the Neva Works, has had an official trial of her engines on the measured mile. In accordance with the regulations, the vessel first made two trips at forced draft, after which the working of the engines was tested in a four hours' trial at nine-tenths of full speed, and the trial was concluded by two more forced runs. The mean speed of all four runs worked out at 26.54 knots, with a displacement of about 203 tons, a mean draught of 4 feet 7½ inches, and a difference of 5 inches. The average revolutions were 401, with a pressure of steam in all the boilers of from 200 to 250 pounds. At the diminished speed of nine-tenths, with the same pressure, the average of revolutions was about 360. The steam was very evenly maintained under the supervision of a French engineer, who is at the works for this purpose. The machinery worked very satisfactorily in spite of the severe test to which they were put, with such a high number of revolutions.—Journal "R. U. S. I."

Nyrok.—The torpedo-boat destroyer *Nyrok* built by the Government Ijora Yard, on the lines of the *Sokol*, has also completed her trials. Her first two runs on the measured mile were made at a speed of 26.18 knots, *i. e.*:

First run, speed attained, . . .	26.47 knots.
Second run, speed attained, . .	25.89 knots.

The speed contracted for was 26.5 knots. During her trial at nine-tenths of the possible revolutions of the engines (*i. e.*, some 360–362), the low-pressure cylinder of the starboard engine partially broke down, and the trial had to be stopped.

Pallada.—The I.H.P. developed by the engines of the first-class cruiser *Pallada* at recent official trials, when the vessel attained a mean speed of 19.2 knots, is shown below.

Starboard engine, 4,542.8 I.H.P., with 165 pounds of steam, the engine making 135 revolutions.

Midships engine, 4,405.6 I.H.P., with 164 pounds pressure of steam, the engine making 154 revolutions.

Port engine, 4,151.8 I.H.P., with 168 pounds pressure of steam, the engine making 134 revolutions.

The grand total of H.P. of all three engines is thus 13,100.2, *i.e.*, 1,490.33 more than contracted for. The figures here given are

the mean from seven series of diagrams, except those for the port engine, which represent only four, as in the latter part of the trial the indicators of the highest-pressure cylinder broke down. The engines are triple screw, and worked satisfactorily during six hours' continuous trial at full draft; they are supplied by 24 Belleville boilers. The total area of heating surface is 36,114 square feet, or more than three square feet to each H.P. as designed, hence the steam was abundant and evenly sustained. The two trips made on the measured mile gave, as regards speed,

First, with the wind, ...	19.5 knots.
Second, against it, ...	18.9 knots.
Mean, ...	19.4 knots.

—Journal "R. U. S. I."

Voron.—The torpedo boat *Voron*, built by the Neva Works, has undergone her taking-over trial on the mile. The highest speed attained was 28.1 knots at 432 revolutions per minute, and the mean speed worked out at 27.5 knots. Although towards the end of the test two of the funnels were found to be leaking, and there was a considerable escape of steam from the waste pipe, the vessel was accepted.

Pobieda—which is the Russian word for "Victory"—is an improved *Peresviet*, and though loosely spoken of as a battleship, really belongs to that hybrid class of ship which the French call "intermediates," the most striking example of which is the Italian *Vittorio Emanuele*. To this class more or less belongs our *Renown* and *Barfleur*, the Italian *Sardegna* and *Vittorio Emanuele*, and the German *Furst Bismark*. Sometimes these are called armored cruisers, but the term is hardly legitimate, just as the term first-class battleship is inappropriate. Hence the happiness of the French phrase. In seeking a definition—and it is by no means merely academic to do so—we must first define an armored cruiser. "A battleship that sacrifices guns and armor for an increase of speed" is perhaps the most correct definition of such a vessel. The "intermediate" sacrifices some gun power and a very little armor for more coal and a small

increase of speed. Whether this is wise or not only a big naval war can decide. Armored cruisers are not intended to fight battleships unless there is a numerical preponderance in their favor; the "intermediate," on the other hand, is intended to tackle the battleship if necessary, pitting her speed superiority against the big battleship's big gun superiority. This is a pretty problem. The trouble is, however, that while it is none too easy to say where the dividing line between armored cruisers and battleships is to be drawn, it is practically impossible to make a demarcation between the battleship proper and the "intermediate." Reckoning by big gun power, the German *Wittlesbach* in an "intermediate;" yet she is essentially a battleship. Compared to the *London*, our *Duncan* is an "intermediate;" but compared to the *Pobieda* she is distinctly a battleship. And so on, and so on.

We preface our article with these remarks, because, in these days of hasty deductions and ill-considered comparisons, the relative efficiency of a warship cannot be even approximately gauged unless such ideas are kept to the front. The prime test of a warship, as good, bad or indifferent, must ever be governed by one chief factor—the work she is intended to do. We, below, compare the *Pobieda* with some other ships of her displacement, but it must be distinctly understood that her *metier* is not necessarily the same. Remarks under this head will, however, come better after we have made the comparison, one that, owing to differences in age, is particularly limited in certain obvious directions. In all the ships given below there is, however, a similarity in the main problem. This has been to secure the most useful features of a battleship and a cruiser upon a moderate displacement.

It will be seen from the table of comparison that designers are by no means at one as to the method of securing this ideal save in armament. In the Italian design it is in numbers of big pieces that the sacrifice is made; in all the others number is not given up, but a medium piece is substituted for the best possible. In quick-firing guns the armament is about that of the ordinary battleship—the 8-inch in the Italian being merely a substitution

of a few heavier guns for a more numerous battery of 6-inch. The additional speed in the Italian ship may be discarded; it is due, perhaps, rather to the advance of ideas in this direction than to seeking after special qualities in that particular feature. When the older ships were designed 18 knots was looked upon much as 22 knots is now—it was a speed of the "catch almost anything afloat" order.

.....	*Pobieda.*	*Peresviet.*	*Bismarck.*	*V. Emanuele.*	*Renown.*
Nationality	Russian.	Russian.	German.	Italian.	British.
Date of launch	1900	1898	1897	Building.	1895
Displacement, tons	12,670	12,674	10,690	12,625	12,350
Length, feet	436	436	394	435	380
Beam, feet	71½	71½	65½	73½	72½
Draught, feet	27½	27½	27	26	28
I.H.P.	15,000	14,500	14,000	20,000	12,000
Speed, nominal, knots	19.25	19	19*	22	18
Guns:					
Main armament	4 10-in.	4 10-in.	4 9.4-in.	2 12-in.	4 10-in.
Secondary armament	11 6-in.	11 6-in.	12 6-in.	12 8-in.	10 6-in.
Tertiary armament	20 3-in.	20 3-in.	10 3.4-in.	12 3-in.	12 3-in.
Small	26 various.	26 various.	10 1-pdrs., 8 Maxins.	12 3-pdrs.	8 3-pdrs., 8 Maxims.
Torpedo, submerged	4	4	5	2	4
above water	2	2	1	None.	1
Armor:					
Belt, ins.	9—4	9—7	8—4	10—4	8—6
ratio, length, ins.	Complete.	⅔ length.	Complete.	Complete.	⅓ length.
Deck, ins	2½	2½	2	4	3
Main turrets, ins.	10	10	8	6-in., inclined.	6-in., inclined.
Bases of these, ins.	9	10	8	8	10
Lower deck side, ins.	5	5	Nil.	8	6
On secondary guns	5	5	4	6	6
Coal, normal, tons	1,063	1,063	1,000	1,000	800
maximum, tons	2,058 + oil.	2,058 + oil.	1,100	2,800	1,760
Boilers	30 Belleville.	30 Belleville.	½ cylinder, ½ Thornycroft.	Not settled.†	Cylindrical.

*This speed has never been reached, 18.7 being highest attained. †Reported Niclausse.

From this it follows that the *Pobieda* being not yet fully complete, is, in a certain sense, out of date. This is so, but the remark applies to all Russian warships. This is due in part to the slowness of Russian construction, in part to the lack of originality, which—despite the fact that Russia has initiated so many original features—characterizes Russian design. The *Popoffkas* were original—too much so, indeed. The *Tcheme* class were original, so, too, their earliest armored cruisers. This phase, however, has perhaps been like German originality—the mark of the amateur as much as anything. The amateur is always prone to strike out on new lines, which, on examination, prove to be little save what more experienced folk have already tried and discarded. This we see operating in all walks of life, and the average naval archi-

tect, as so many ships witness, is no less frail than other people. Now, having served some apprenticeship, Russia, like Germany, is more content to do what the Japanese have always done, seek the efficient thing rather than the merely novel. We see this in the Russian fleet, the *Three Saints* being nothing more than a *Trafalgar* of more modern date, the *Poltava* class, the United States *Indiana* with a higher freeboard, the *Peresviet* and *Pobieda* practical adaptations of the British *Renown*.

They are also improvements. There is more water-line belt. For it barbette strength is partly sacrificed. This is a weakness *per se*, but the 10-inch guns of the *Renown* have rather more protection than they are worth, and the curious Russian barbettes—adapted from Germany, apparently—will need a good many shell about them before they are isolated enough to topple over.

The table above gives the principal details of the *Pobieda*. The big guns are in fore-and-aft turrets of Harvey nickel, made, like everything else in the ship, at the Baltic works. These are 10 inches thick till the protective deck is reached, and they are carried some little distance below this at 5 inches thick. The forward turret has a rather limited arc of fire—intentional presumably—of about 200 degrees. The after one has an arc of about 270 degrees. The object of the bow 6-inch is a mystery. It marks the persistence of a very old French idea that was a survival of the Nelson period, a time when guns had next to no arcs of fire, and were distributed accordingly. This bow gun is unprotected, but being in a place where hits are not very probable, this is a minor matter. The trouble is that its arc of fire is very limited—less than 60 degrees either side—so that it cannot be used on the broadside at all, or even nearly on the broadside. It is, therefore, chiefly 10 tons odd of metal in the extreme bow, a place where no ship wants useless weight. The other ten 6-inch pieces, 45-caliber Obuchoff quick-firers with the Canet breech, in 5-inch Harvey-nickel casemates, are placed very well as regards fire arcs and non-interference, though the midship guns are liable to be put out of action by shell underneath them. The arrangement, it will be noted, is exactly reproduced in our

County class. The positions of the 12-pounders are indicated in the illustrations, and call for no remarks.

The belt is complete, and of Krupp cemented steel. It is reinforced by the armor deck. Above it, for a length of about 185 feet amidships, is a redoubt, also of Krupp steel, 5 inches thick, and, like the belt, 7 feet 6 inches high. It is terminated by traverse bulkheads.

The machinery consists of three sets of vertical triple-expansion engines, actuating three screws. These are tactically an error in a battleship, whatever else may be said of them. There is less energy to expend in turning with the screws. Turning, however, is not the *Pobieda's* strong point, her circle being about 750 yards.

The *Pobieda* did her first trials some months ago, being then in a very incomplete state, and without her armor on. Whether or no she was weighted to her designed displacement we cannot ascertain. She reached 15,492 indicated horsepower, and with 102 revolutions made 18.51 knots; 102 revolutions was the designed number for 19 knots. The data of Russian trials are, however, always somewhat uncertain. The *Peresviet*, by official Russian accounts, with 102 revolutions got 19.12 knots with an expenditure of 13,775 indicated horsepower only on a six-hours' trial. The *Pobieda* is nominally somewhat the faster ship; the report of her trial is not official and may be incorrect, otherwise the slight difference in beam and draught has proved an unfortunate improvement. Accounts of the trial say the ship was water-ballasted to a draught of 25 feet forward and 25½ feet aft. The *Peresviet* draws 27½ feet, the *Pobieda* is supposed to draw a little less; therefore, if these figures are correct, the trial did not represent her completed under-water form. But, as we have said, Russian data are rarely trustworthy. The consumption, according to the same accounts, was the enormous one of 2.65 pounds. Ideal consumption is 1.5 pounds, a high consumption is 2 pounds.

There are thirty Belleville boilers in six groups served by three uptakes. The three sets of engines are each of 5,000 indicated horsepower. Boiler pressure is 165 pounds to attain this result. It is reduced to 139 pounds at the engines. Our

Bellevilles have 300 pounds at the boilers, reduced to 250 pounds at the engines. In addition to coal the *Pobieda* carries some liquid fuel in her double bottom. The coal is stowed above and below the protective deck admidships. Four of the *Peresviet's* boilers are without economizers, and placed 6½ feet higher than the others, the idea—a pet Russian one—being to use these should the boiler rooms be flooded and the other fires put out. This was asked for in the *Tsarevitch*, but French builders rather scoffed at the idea as impracticable. We must confess that we have a difficulty in picturing these boilers being used under the assumed conditions unless they are entirely away from the others.

The big guns are electrically maneuvered as well as by hand power, and electric hoists are fitted to all guns.

In conclusion, it may be observed that the *Pobieda* is designed for service in the far East, probably with a view to filling the double *role* of battleship and cruiser as circumstances may demand.—London "Engineer."

The Russian Navy.—The Russian Government has decided to devote a special credit of 15,000,000 roubles to the construction of new ships. No further Russian ships of war are to be built in foreign yards.

SWEDEN.

Dristigheten.—This new coast-defense battleship has satisfactorily concluded its steam trials, having under forced draft attained a speed of 17 knots. Her principal dimensions are as follows: Length, 285 feet; beam, 48 feet 7 inches; draught, 16 feet on a displacement of 3,450 tons. Her engines were to make 6,000 I.H.P. under forced draft, and 5,400 I.H.P. under natural, the speed being 17 and 16.5 knots respectively, which has been reached at the trials. Steam is generated by twelve Yarrow water-tube boilers, with a grate surface of 136 square feet, and a heating surface of 4,712 square feet. The cylinders have a diameter of 724 mm. (28.66 inches), 1,133 mm. (44.6 inches), and 1,755 mm. (69.1 inches) respectively, with a stroke of 693 mm. (27.7 inches). The steam pressure is 14.7 kg. per square centimeter.

Protection is afforded by an 8-inch water-line belt, tapering to

4 inches at the extremities, the plates having been made at the St. Chamond and Krupp Works; the central citadel for the secondary armament is protected by 4-inch armor, and the turrets for the two heavy guns by 8-inch plates in front and 6-inch in rear; the armored deck is two inches thick and the conning-tower 8 inches. The armament consists of two 8.2-inch 42-caliber Bofors guns, one in each turret forward and aft; six 5.9-inch 45-caliber Q.F. Bofors guns in the central battery with splinter bulkheads between, fifteen 6-pounder Q.F. guns, and two submerged torpedo tubes, Elswick pattern.—Journal "R. U. S. I."

Tapperheten, Vasa, Aran.—The three coast-defense battleships *A*, *B*, and *C* were all launched last year, receiving the names of *Tapperheten*, *Vasa* and *Aran* respectively. They are all three to be completed for sea during the present year. They are 200 tons larger than the *Dristigheten*, with two feet greater length, 8 inches more beam, and a draught increased 5 inches on a displacement of 3,650 tons. The I.H.P. and speed remain the same as in the earlier ship. The armament also remains the same, but the six 5.9-inch Q.F. guns are carried in single turrets instead of a central battery, which are protected by 6-inch plates in front and 2.5-inch behind. The thickness of the armor plates has been somewhat reduced, but their resisting power remains the same, the extreme thickness of the belt being only 7 inches; the armor on the fore turret is 7.8 inches thick, and on the after 5.8 inches, the lower barbettes being 7.8 inches. The small revolving turrets for the 5.9 inch Q.F. guns are protected by 6-inch armor, tapering to 2.4-inch in the rear, while their barbettes are of 4-inch steel. The armored deck is 2 inches thick, and the conning-tower 7 inches. The whole of the armor has been provided by Krupp, with the exception of that for the barbettes of the 5.9-inch guns, which, as been manufactured by the Bofors Works in Sweden. The water-tube boilers are of the Yarrow type, and, with the engines, are the same as in the *Dristigheten*.—Journal "R. U. S. I."

Coast-Defense Plans.—The plans for a new coast-defense ship have been approved. She will differ from the earlier vessels in having the armored deck somewhat thicker over the boilers,

while the supporting and ammunition tubes for the turrets of the 5.9-inch Q.F. guns are to be strengthened, but at the expense of the turrets for two heavy guns, which will have rather weaker armor. In view of the unfortunate delays which have attended the delivery of armor in the past, with the exception of the plates for the armor deck and the ammunition and communication tubes, the contract for the armor will be given to Krupp.—Journal "R. U. S. I."

Svea, Göta, Thule.—The work of reconstructing the three old coast-defense ships, built between 1886 and 1892, viz: the *Svea*, of 2,900 tons, and 14.7 knots speed, the *Göta*, of 3,100 tons and 16 knots speed, and the *Thule*, of 3,150 tons and 16.2 knots speed, is now almost completed, and the ships should be ready for their trials this spring. In place of the earlier armament of two 25-cm. (10-inch) Elswick guns in a single turret forward, and four unprotected 5.9-inch guns, the ships will now carry one 8.2-inch Q.F. gun in a turret forward, three 5.9-inch Q.F. guns in single turrets on each broadside, and aft, also in a turret, another 5.9-inch Q.F. gun, while eleven 6-pounder Q.F. guns will be distributed on the upper deck and bridges.—Journal "R. U. S. I."

Destroyer.—The first torpedo-boat destroyer for the Swedish fleet is being built by Messrs. Yarrow at Poplar. With a length of 220 feet, a beam of 20 feet, the vessel will have a displacement of 320 tons. The contract speed is to be 31 knots during a three-hours' trial under forced draft, with a three-inch air pressure and 35 tons extra lading. The vessel is divided into seven water-tight compartments, and her armament consists of six 6-pounder Q.F. guns, and two torpedo discharges. She has two 4-cylinder triple-expansion engines, steam being supplied by four Yarrow boilers, which are protected by the coal bunkers. She is to cost £48,300, with a premunm of £500 for each quarter of a knot over the contract.—Journal "R. U. S. I."

MERCHANT STEAMERS.

Columbia.—Built to the order of the Anchor Line Steamship Co. This is by far the largest and finest vessel built for the Glasgow and New York trade. She has a straight stem and an elliptical stern, with two steel pole masts of fore-and-aft schooner rig, and her bridge house, poop house, and forecastle are spacious and commodious. There are six decks, so that both the comfort of passengers and the rapid handling of cargo are secured, and the vessel is divided into nine watertight compartments. The first-class accommodation, which is situated amidships, includes staterooms for 216 passengers on the main and bridge decks. The staterooms on the bridge deck for one, two, or three passengers, are a special feature of this vessel. They are luxuriously fitted up with roomy couches, mahogany folding washstands, wardrobes, two electric lights, one with switch at door and the other with switch at bedside, and have large, square windows, which admit much more light than the ordinary bull's eye, fitted with ornamental shutters, and a handy screw ventilator, which can be adjusted at will.

The main saloon is a very handsome apartment, situated on the upper deck, well lit, well ventilated, and heated throughout by copper pipes in massive marble-topped radiators, insuring that it can be made comfortable and attractive at all seasons of the year. The furniture and general appointments are handsome; there is more than the usual space between the tables, many of which also are small, for the convenience of family parties wishing to dine by themselves. Altogether the saloon is an excellent ocean dining room. Immediately above the main saloon, on the bridge deck, and easy of access by the grand staircase, is the library, a spacious and well-appointed room, 36 feet by 36 feet, fitted with bookcases containing an assortment of books intended to suit all readers, elegant and completely equip-

ped writing and other tables, and many comfortable settees. A handsome stairway leads to the promenade deck, where there is an airy smoking room, with domed skylight and large windows all round. The walls are of the solid fumed oak of a handsome, dark appearance, and arm chairs and settees, with conveniently-placed tables, are arranged so as to give the maximum of comfort with the minimum of trouble.

The chief want upon modern ocean liners is easily-accessible and commodious accommodation for promenading and for deck seats. The *Columbia* has been specially arranged so that the first-class passengers will have a long bridge deck and a promenade deck 230 feet in length at their disposal, with waterproof shelters on both decks, and a wind screen at the forward end. Electric lights are fitted so as to make these decks as light by night as by day, while cross passages have been provided for the convenience of passengers. The second-class accommodation is also fitted amidships, toward the after end of the vessel, and includes staterooms on the main deck for about 400 passengers, whose comfort and convenience, in every respect, have been excellently catered for. Here the other appointments include an excellent dining saloon, library and smoking room. For both first and second-class passengers all manner of games are provided, from sea quoits to ping-pong. Special attention has been devoted in the *Columbia* to the third-class passenger accommodation, which is situated on the main and 'tween decks, and is intended to provide for 750 passengers. The married people, families and single women are berthed in separate cabins on the main deck and after 'tween decks; separate rooms are provided for single men, and they are likewise quartered in open apartments. Ample dining accommodation is provided, and the owners now supply bed and bedding, nice white tablecloths and eating utensils of every kind for this class. Hot water can be obtained at all times. There is a sitting room for women and children, a smoking room and well-lit covered corridors.

Considerable care has been taken in the equipment of the culinary department. There are two galleys, both of unusual

size. That for the first-class is fitted with a large cooking range of the latest design, with silver grills, steam stockpots, steam vegetable cookers, and hot closets, all arranged so as to be conveniently got at by the numerous chefs; that for the third-class contains a most complete steam cooking plant. The crew's galley is provided with steam and coal-cooking apparatus for the preparation of good, substantial fare. A large cold-storage chamber, with separate accommodation for fish, vegetables and meat, has been placed in a convenient situation, and powerful refrigerating machinery is provided, not only to maintain the cold chamber at the necessary temperature, but to supply the large quantity of ice which is daily required by American passengers.

With regard to the engines of the vessel, the *Columbia* is propelled by two sets of powerful triple-expansion engines of the latest type. The steam-steering gear is of special design, angled barrels and gear wheels of annealed cast steel, while a patent liquid controlling brake has been fitted to avoid jarring and straining in heavy weather. For the handling of cargo, the new liner has been provided with specially large hatches, which are required for the bulky electrical and other machinery, rails, ironwork, etc., which are now exported from America to Britain. The cargo will be loaded and discharged by means of ten horizontal winches. A comparison of the dimensions of the *City of Glasgow*, which sailed on her maiden voyage from the Clyde fifty years ago, with those of the new vessel gives an interesting indication of the growth and development of the trans-Atlantic trade during the past half century. The length of the *City of Glasgow* was 220 feet, her breadth 32 feet, her depth 21 feet; her engines, overhead beam and jet condensing; and her gross measurement 1,600 tons. The *Columbia*, as already stated, is 8,400 tons burthen, has twin-screw engines of triple expansion, and is 500 feet long, 56 feet broad and 36 feet deep.—"The Steamship."

The New American Liner Haverford.—The large twin-screw steamer *Haverford* is of the "intermediate" class, in which the claims of large cargo-carrying capacity exceed those of speed, and yet in which sufficient speed is maintained to make it worth while to provide extensive passenger accommo-

dation. Many passengers now prefer to travel by these vessels rather than by the faster liners.

The main propelling machinery of the *Haverford* consists of two sets of vertical triple-expansion engines of the usual inverted marine type, each cylinder driving a separate crank. The diameter of the H.P. cylinder in each set is 29 inches, the diameter of the I.P. 46½ inches, and the diameter of the L.P. cylinders in each set is 75 inches, with a stroke of 4 feet 3 inches. The slide valves are of the piston type for the H.P. and of the flat-faced type for the I.P. and L.P. The valve gear is of the double-eccentric double-bar link motion. The air pumps are driven by levers off the crosshead of the I.P. cylinders. A direct-acting steam reversing engine is fitted to each set of engines, and the levers of the reversing shaft are fitted with screw gear to admit of the adjustment of cut-off being made in one cylinder independently of any of the other cylinders. The cylinders, liners, covers, front and back columns, condensers and sole plates are all of cast iron, the condensers forming part of the main engine framing. All the shafting is of steel, and each crank shaft is of the built type, in three interchangeable pieces. The main bearings, thrust shoes and tunnel blocks are all lined with white metal. The propellers are four-bladed, the bosses are made of cast iron, and the blades of manganese-bronze.

The auxiliary machinery consists of two centrifugal pumps for circulating the water through the main condensers; two vertical simple pumps with float gear, capable of feeding the boilers when working at full power; two ballast pumps; one sanitary and one fresh-water pump; and a donkey boiler feed pump. There are also a feed heater and filter, and a very complete distilling plant. An Aspinall governor is fitted to each engine.

For the generation of steam there are two double-ended and two single-ended boilers. The double-ended boilers are 16 feet 8 inches mean diameter by 19 feet long, and the single-ended boilers are 16 feet 8 inches mean diameter by 11 feet long. Each of the double-ended boilers has eight furnaces, and the single-ended boilers have four furnaces, being twenty-four in all. These furnaces are of the Morison suspension type, 3 feet 4½ inches inside diame-

ter, with the back ends made on the Gourlay-Stephen principle, whereby a defective furnace can be taken out of the boiler without disturbing any other part of it. The end plates of the boilers are all flanged inwards to meet the shell and the furnaces.

Each opposite pair of furnaces in the double-ended boilers has a common combustion chamber, and in the case of the single-ended boilers each furnace has a separate combustion chamber. The combustion chambers are all securely stayed to the boiler shell and ends. The combustion-chamber tops in the single-ended boilers are supported by girders in the usual way, while those in the double-ended boilers are supported by stays attached to the shell of the boiler. The end circumferential seams are double riveted, and the middle circumferential seams are treble riveted. The double butt-strap longitudinal seams are also treble riveted with five rivets per pitch. The cross seams in the end plates are all double riveted, and all the rivet holes were drilled after the plates had been bent and flanged and fitted together in place, after which they were taken apart and the burrs cleaned off the rivet holes.

The boiler tubes are all of iron, 7 feet 5 inches long between the tube plates and $3\frac{1}{4}$ inches external diameter. The common tubes are No. 7 B.W.G. thick, and the stay tubes are $\frac{1}{4}$ inch, $\frac{5}{16}$ inch and $\frac{3}{8}$ inch thick, to suit their respective loads. The common tubes have the front ends swelled $\frac{1}{16}$ larger in diameter than the back end, and the stay tubes have been staved up in a hydraulic press till the thickness at the screwed ends is the same at the bottom of the thread as the body of the tube. There is 11 inches clear space between the nests of tubes for access for cleaning. The boilers work under natural draft at a working pressure of 160 pounds per square inch.

The dimensions of the *Haverford* are as follows: Length between perpendiculars, 530 feet; breadth, 59 feet; depth, molded to upper deck, 39 feet; and the gross tonnage is about 11,500 tons. The vessel has been built to Lloyd's highest classification, and has been additionally strengthened against the heavy weather of the North Atlantic. There are ten watertight bulkheads, so arranged that flotation may be maintained with any

two compartments flooded. The bunkers are of ample capacity, and are arranged so as to protect the boilers should the vessel be used for transport service in time of war.

The cargo holds occupy the whole of the ship below the upper deck, except the portions required for machinery and bunkers and the store rooms in the peaks.

The cabin accommodation is entirely above the shelter deck, and is placed in a bridge house about 150 feet long, extending the full width of the ship. There are large and airy staterooms for 150 passengers along the sides, and a handsome dining saloon at the forward end is capable of seating 112 persons.

Overhead is the cabin passengers' promenade, upon which are placed the officers' and captain's rooms, the entrance hall, and ladies' sitting room, in a house at the forward end. At the after end, abreast of the engine casing, is another entrance lobby, communicating with a large and comfortable smoking room on the starboard side and a handsomely finished library on the port side. Over these houses come the boat decks, and the wheel-house and navigation bridge, the latter being well protected by a steel bulwark.

In order to enhance the safety of the ship and ensure sufficient immersion of the propellers when crossing in light trim, deep ballast tanks are provided in two of the holds extending to the lower deck; these, with the usual water ballast contained in the cellular double bottom, can give a total quantity of about 4,000 tons of water ballast.

A sister ship of the *Haverford*, to be called the *Merion*, is also being built by Messrs. John Brown & Co., Ltd.—"Exchange."

Minnetonka and Minnewaska.—These ships are of the regular ocean type, designed to have a deadweight capacity, at 25 feet 6 inches draught, of 7,000 gross tons cargo and 700 tons of bunker fuel. Owing to the dimensions of the Canadian canal locks, a limit of 44 feet (extreme) was placed on the beam of the vessels. General dimensions are: Length over all, 443 feet 6 inches; length between perpendiculars, 430 feet; breadth, molded, 43 feet 7½ inches; depth, molded, to upper deck, 33 feet.

They are built to the highest class (100A) of the British Lloyds.

The material is steel throughout, and the vessels have been built under the three-deck rule. They are exceptionally heavy in scantlings. A double bottom, 4½ feet deep, on the cellular principle, with solid floors at every frame, extends from the collision bulkhead to the after-peak bulkhead, with a total capacity, including peak tanks, of 1,600 gross tons of water ballast. The upper and main decks are laid complete, but the lower deck is not completely laid, as it was thought advisable to leave open space between beams, so as to facilitate stowage of cargo; but, as the beams are spaced 4 feet apart, a deck could be laid temporarily, if necessary, and made to suit the cargo to be carried. The forward hold is divided into three compartments by two watertight bulkheads, the after compartment forming auxiliary bunker and connected to stokeholds by tunnel through permanent bunkers and watertight door in bulkhead. The after hold is divided into two compartments, making five compartments all told, with entire internal capacity for cargo of 360,000 cubic feet. There are nine hatches, and, owing to their size, they give exceptional facilities for the rapid discharge of cargo. As the hatches are all of the same width, viz: 14 feet, they admit of a very satisfactory arrangement of girders under beams, which, with a double row of widely-spaced hold stanchions, make a strong structure and allow of easy stowage of cargo.

The cargo-handling gear consists of four short steel pole masts, on each of which is fitted four large derrick booms, and in addition, for working No. 5 hatch over auxiliary bunker, two short derrick masts are fitted, each equipped with a cargo boom. There are nine double-cylinder steam winches (one for each hatch), fitted with friction drums for the hoisting of cargo, which will all be done by flexible steel wire rope. Steam for the winches and other auxiliary machinery is supplied by a large donkey boiler, located on upper deck in bridge house amidships.

Accommodations for the captain are located in a deck house on the bridge deck, and consist of chart room and bed room with stairway from the former to the dining room below. The dining room, with kitchen, pantry and refrigerator adjoining, is located on the upper deck at the forward end of the bridge house, which

contains also rooms for deck officers, engineers, steward and petty officers, mess rooms, store rooms, etc. Quarters for assistant engineers and oilers, together with engineers' bath room, etc., are located on the main deck abreast of the engines, with stairway entrance from alleyways under bridge. Firemen and seamen are quartered on the main deck forward and their mess rooms, wash rooms, etc., are on the upper deck under the forecastle.

A complete installation for electric lighting is fitted, the two generators having 10 kilowatt capacity each. The steering engine is located at the after end of the engine casing on the upper deck, and is operated by rods and bevel gears from the pilot house. Steering rods and chains are led over the deck alongside hatches and attached to quadrant in the after house, in which house is also fitted the auxiliary hand-steering gear. The steam windlass, located on the forecastle deck with engine below, is of large size for handling of the 2¼-inch cables and 7,000-pound anchors. Boats and life-saving appliances are located on the bridge deck amidships.

The main engines, designed to develop 2,400 I.H.P. at seventy revolutions, are of the triple-expansion, vertical, direct-acting type, with three cylinders, 27, 42½ and 73 inches diameter by 48 inches stroke. The high-pressure cylinder only is fitted with a liner. Cylinders are arranged from forward in the order of high-pressure, intermediate and low-pressure. The high-pressure and intermediate valves (piston and double-ported slide respectively) are placed between these cylinders, and the low-pressure double-ported slide valve is between the intermediate and low-pressure cylinders. The bedplate is in three pieces, bolted together, and contains six main bearings, 14 inches in diameter and 14 inches long, lined with white metal in cast-iron circular bushings. The condenser, which is of cast iron, rectangular section, extends about two-thirds the length of the engine at the back, supporting on its top two of the back columns. It contains 3,120 square feet of cooling surface, made up of ⅝-inch brass tubes. The circulating water is pumped twice through by a 12-inch centrifugal pump, driven by an independent engine. The three front and forward back columns are of the inverted Y pattern, allowing

free access to crank pins and bearings. The piston rods are of steel, 6¾-inch diameter, and the connecting rods are 10 feet between centers. The crank shaft, which is in three interchangeable parts, 14 inches diameter, is of forged steel with wrought-iron crank arms, with the cranks arranged on the Yarrow-Schlick-Tweedy system. The crank pins are 14 inches diameter by 15½ long. Tunnel and propeller shafts are of forged steel, 13¼-inch and 15¼-inch diameter respectively, the latter being protected in the stern tube by a continuous brass liner. This liner is shrunk on in five lengths, the ends of which are fused together by the pouring of molten brass over the joints. The valve gear is Stephenson double-bar link motion throughout, the reversing engines, being of the direct-acting type.

The air pump is of the vertical single-acting type, driven from the low-pressure crosshead and fitted with bronze disc valves. Two feed and two bilge pumps are also driven from air pump crosshead, the feed pumps taking water from the hotwell and delivering to the feed heater, from whence the feed water gravitates to the duplex vertical main feed pumps, by which it is pumped to the boilers through an oil filter. The donkey and ballast pumps are vertical duplex type, the latter being arranged so that it may be used as a circulating pump. The donkey-boiler and evaporator feed pumps are horizontal duplex. The main steam pipe is of 9-inch lap-welded iron with riveted cast-steel flanges, the connections to the four boilers being made of solid-drawn copper tubing with suitable expansion bends and slip joints. Auxiliary steam and exhaust pipes are copper, and bilge suctions lead.

The main boilers are four in number, of the Scotch type, 12 feet mean diameter by 11 feet 6 inches long, with a working pressure of 170 pounds per square inch. Each has two Morison interchangeable furnaces of 44 inches mean diameter, with separate combustion chambers and 226 tubes of 3-inch diameter. The total grate surface in the four boilers is 148 square feet, and the heating surface 6,900 square feet. The boilers are fitted with Howden draft, with a large single fan and belted engine. The donkey boiler, which will supply steam for the nine cargo

winches, is of the Scotch type, 10 feet 6 inches diameter by 10 feet 6 inches long, with two 40-inch furnaces and 158 tubes of $3\frac{1}{4}$ inches diameter. It is placed above the main boilers on the upper deck and connected to the forward main funnel. Ashes are hoisted up stokehold ventilators by small double-cylinder engines, buckets being transferred to chute at ship's side on overhead trolleys.

The propeller is of cast iron, 18 feet 6 inches diameter by 17 feet pitch, with 94 square feet of surface on four removable blades.

The engines are supplied with a very complete outfit of engineers' tools, etc., and spare gear in excess of Lloyds' requirements.—" Marine Review."

Hull and Machinery Data of Late Trans-Atlantic Steamers.

Steamers	*Campania.*	*Kaiser Wilhelm der Grosse.*	*Oceanic.*	*Deutchland.*	*Kronprinz Wilhelm.*	*Savoie.*
Built in	1893	1898	1899	1900	1901	1901
Length, feet	622.4	622.4	705.4	684	663.3	582.3
Breadth, feet	65.3	65.9	67.9	66.9	65.9	60
Depth, feet	44.6	42.9	49.2	43.9	42.9	39.3
Draught, feet	—	27.8	32.4	28.8	27.8	25.4
Displacement, tons	18,000	20,900	28,500	23,200	21,300	15,400
I.H.P.	29,600	27,610	24,660	35,500	32,550	21,700
Speed, knots	22	22.75	20	23 50	23.20	20.50
Officers and men	413	450	394	543	522	383
Passengers	1,700	1,580	1,710	1,283	1,650	1,075
Type of engines	Triple exp.	Triple exp.	Triple exp.	Quad. exp.	Quad. exp.	Triple exp.
No. and diam. of cyl's:						
H.P., inches	2 × 37	51.96	47.47	2 × 36.61	2 × 34.25	44 49
1st I.P., inches	80.38	89.76	74.09	73.62	68.8	68.50
2d I.P., inches	80.38	89.76	74.09	103.93	98.42	68.50
L.P., inches	2 × 98	2 × 96 45	2 × 92.98	2 × 106.30	2 × 102.36	2 × 80.31
Stroke, inches	69	68.89	72.04	72.83	70.86	66.93
Ratios of cylinders	1-2.36-7	1-3-6.9	1-2.43-7.7	1-2.4-4-8.4	1-2-4[illegible]-8.9	1-2.37-6.52
Boiler pressure, pounds	167	177	192	213	213	170
Revolutions per minute	79.5	77 to 78	—	77 to 78	80 to 82	84
Number of boilers	12D, 1S	12D, 2S	15D	12D, 4S	12D, 4S	16S
furnaces	100	104	96	112	112	.64
Total grate surface, sq ft.	2,627	2,594	1,938	2,196	2,702	1,827
heating surface, sq. ft.	82,100	84,400	74,060	85,580	93,660	45,550
Cooling surface, sq. ft.	82,100	35,550	74,060	43,060	41,210	32,530
Propellers, diam., feet	23 48	22.3	20.25	22.3	21.82	21.32
pitch, feet	30.5	32.8	—	32.8	32.8	25.58
Nature of draft	Assisted.	Assisted.	Assisted.	Forced.	Assisted.	Forced.

Sithonia.—STEAMSHIP, HAMBURG-AMERICAN LINE. FREIGHT STEAMER FOR EAST ASIATIC SERVICE.—Three cylindrical boilers and one donkey; 15 A. pressure; 3,658 mm. length, 4,394, diameter; 5.18 qm. grate, 214.51 qm. H. S. The boilers are arranged for burning liquid fuel. The apparatus is shown in Figs. 1 and 2.

Instead of the usual steam-jet pulverizers, in which a part of the available heat is lost because the steam injected onto the fire has to be brought to a high temperature during the process of combustion, there are here arranged centrifugal pulverizers. The

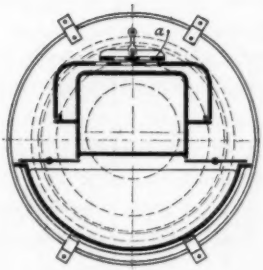


FIG. 1.

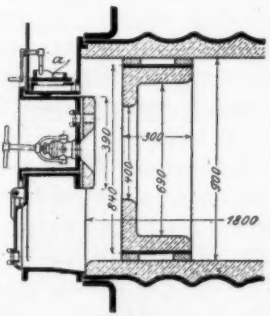


FIG. 2.

FURNACE ARRANGEMENT FOR LIQUID FUEL.

liquid fuel is brought from the oil tanks by a steam pump that is situated in the double bottom and at the side of the engine room. Figs. 3 and 4 show that arrangement of the pumps and the piping. A heater is installed in the suction and in the pressure lines, and in these the thick oil is thinned by means of steam coils and thus made suitable for passage through the pump and the pulverizers. These will heat 1,500 liters per hour oil to 95 degrees centigrade, of which one-third is done in the suction and two-thirds in the pressure line.

For cleaning the oil there are two filters of which, however, only one is in action at one time. The other one answers as reserve, similar to that of the second steam pump.

The lower part of the pulverizer pan is provided with screw threads by which the ejected stream is put in rotation. Below the tuyere there is a sieve which retains dirt. That these openings may be easily looked after in case of obstructions, the easily removed cover is arranged as can be seen by the figure.

As the pumps are run faster or slower the force of the fire is

regulated, while the control of the admission of air is handled by a valve A in figs. 1 and 2.

The internal walls of the fire tubes are provided at their

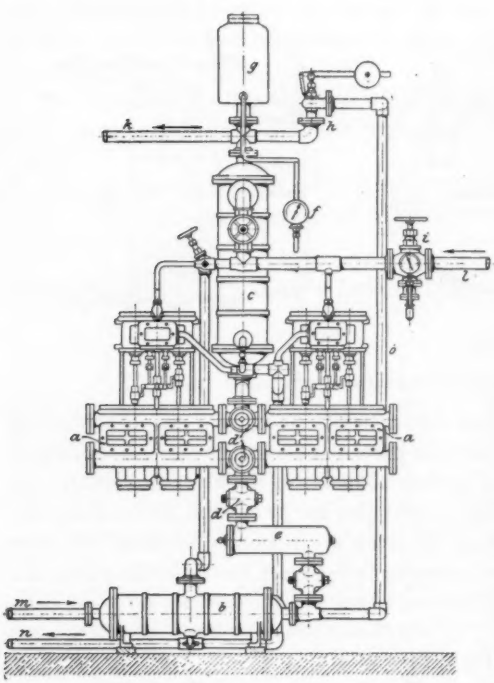


FIG. 3.

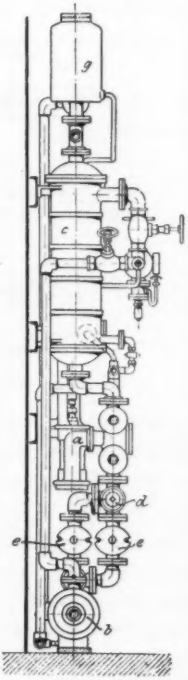


FIG. 4.

PUMPS AND PIPING FOR THE LIQUID FUEL.

a. Steampumps.
b, *c*. Heaters.
d. Three-way cock.
e. Filter.
f. Gauge.
g. Airchamber.
h. Relief valve.
i. Throttle valve.
k. Pipe line from liquid fuel to atomizer.
l. Steam admission line.
m. Liquid fuel admission line.
n. Pipe line for condensing water.
o. Relief line.

forward section with a fire-proof cover; the ring of fire-proof material placed forward is held in a cast-iron ring and serves for the proper distribution of the flame.—"Zeitschrift."

Cargo Steamers; Consumption of Coal.—In his address, as President of the Institution of Marine Engineers, Mr. John Corry gave particulars as to the coal consumption of large cargo steamers. One of these, displacing 10,085 tons gross, measured 393 feet 5 inches in length by 46 feet 8 inches beam by 31 feet molded depth, and her deadweight capacity was 6,900 tons. Her engines had cylinders 26½ inches, 44 inches and 73 inches in diameter by 48 inches stroke, to which steam was supplied by three single-ended boilers, with 152 square feet of grate area and 6,270 feet of heating surface. Howden's system of forced draught was used. On the run from London to Melbourne, at an average speed of 11.9 knots, the coal consumption was 33 tons per day for all purposes; the engines indicated about 2,350 horsepower. Another boat referred to was of fuller model, being 440 feet long by 53 feet 1 inch beam by 33 feet 1 inch molded depth. The displacement on a draught of 26 feet 11 inches was 14,395 tons. Her engines had cylinders 27 inches, 46 inches and 78 inches in diameter by 48 inches stroke, and indicated about 3,000 horsepower. The four single-ended boilers, supplied with Howden's system of forced draft, were designed for a working pressure of 200 pounds per square inch, the total grate area being 194 square feet, and the heating surface 7,849 square feet. The run from London to Adelaide was made at a speed of 12.04 knots per hour, with a consumption of 42 tons of inferior Welsh coal per day.—"Engineering."

YACHTS.

Weetamoe.—On the stocks in the yard of George Lawley & Sons, South Boston, very nearly completed, is a new bronze racing sloop that is claiming lots of attention in yachting circles, not alone because of the modern features produced in her type of racer, but because of the fine mechanical skill developed in the job of plating the hull, which can truly be said to be incomparable.

Shut in all over, from keel to rail, as this craft is at present, the riveters have not yet completed more than two-thirds of their work, but the job mechanically has been pronounced by prominent yacht designers to be the feature of the season in yacht construction.

The yacht is the 60-rating sloop *Weetamoe*, being built to the order of Mr. H. F. Lippitt, of this city, prominently known in yachting as owner in past seasons of the famous sloop *Wasp*, and more recently the schooner yacht *Quisetta*. The *Weetamoe* is from the design of Gardner & Cox, of New York, and is what may be regarded a boat radical in type regarding some of the features, but a craft at the same time as powerful, according to size, as the more recent cup defenders.

She is a deep keel boat, and, though having a hollow section, can be almost regarded as a boat of plate-fin characteristics. In some respects she resembles the 70-footers built two years ago, and also the *Columbia*. Her chief characteristics in departure from other similar types are in the extremely long, slender ends, with the wetted surface aft, cut to decided extremes, and the easy, round form she exhibits when one glances over her midship section.

No one who has viewed the craft inside and out can fail to be impressed with the all-round easy form and with the lightness of construction, the heaviest plates on the garboard weighing 6

pounds to the square foot, and the sheer-strake plates being fully a pound lighter to the square foot.

The design is one that from the extremely sharp ends and apparently fair-balanced fin ought to give the *Weetamoe* excellent qualities in windward work, while in down-the-wind conditions her lightness of construction should be quite a factor in speed, when the light ends are taken into consideration.

On the after overhang the surface is so extensively cut that at the first glance one gets of that section of her lines there is a suggestion of flatness which, when studied for a few moments, reveals the cleanly turned curves on the skin surface. The lines of the after overhang and those of the floors in the mid-section are the nearest approach of any others in the model to flatness, Shoaling well out, the after overhang plating terminates a distance of 3 feet forward from the taffrail, when a wide stern plate reaches upward at an easy incline until it is connected with the saucer-edge-shaped taffrail, giving in effect a finely-curved sternboard, and a credit to the workmanship.

The stem casting for the greater part of its length is straight in outline, commencing on such line just under the step of the mainmast and running with little indication of a curve several feet forward of the water line.

The bottom of the lead keel is on a line parallel with the boat's waterline, while both ends of the lead rake to the same extent, something like 40 degrees. There is an easy deadrise, and, as above said, the curves are clear in the midship section.

Like the *Syce* and other boats from the boards of the designers of the *Weetamoe*, the latter's rudder is not hung upon the after end of the keel; instead there is a rudder somewhat after the plan of the balance rudder in the Newport 30-footers, only there is no part of it projecting forward of the rudder post. It is hung upon a skeg formed by a jog of frames and plate, the lower end describing an acute angle several feet abaft the end of the aft end of the lead keel, and directly under the cockpit. The *Weetamoe* will be steered by a tiller from the cockpit.

She will have a well-defined sheer aft, the lines being straighter

on deck forward. The deck has a crown of five inches, and is spacious for such a sharp-ended craft.

Concerning the details of construction of the new Lippitt racer, all the modern ideas in the building of metal boats have been introduced, and, besides, the craft is not without innovations in this line.

The boat is plated throughout with Tobin bronze, and a new feature is the fastening of 22 frames of that reliable metal in the midship section for the purpose of overcoming galvanic action, which, as is well known in yacht construction, is deteriorating in effect immediately where the greatest dampness collects—in the wake of the lead keel. All the other body frames, together with the deck frames, are of nickel-steel. The deck stringers, a foot wide on each side and 1⅛ inches in thickness, the floor plates, over the lead, diagonal braces, rudder and end castings are of Tobin bronze.

The lead keel, weighing 22 tons, is fashioned much after the plan of the more recent cup defenders. Short and deep, its surface has shapely lines. It is 14 feet long on top, and 11 feet on the bottom. Its greatest depth is 4 feet 3 inches, and at its widest part, a couple of feet abaft the forward end, it is 2 feet 2 inches in thickness. Inside, webbed plate castings connect the lead and the butts of the frames, the fastenings being after the lag-screw method.

The frames are spaced 15¼ inches apart, and are webbed and bulbed 2⅛ by 1⅛ inches, excepting in the wake of the mainmast and chainplates. In the mast wake are two nickel-steel 5-inch web frames, continuing in an unbroken line around the interior of the boat, forming deck beams, body frames and floor plates. These web frames are in form of a Z bar. There is one of these Z bars in the wake of the chainplates, where part of the greatest tension develops in a race. Other frames in that location are 3-inch bulbed angle bars.

Including the garboard and sheer plates, there are five strakes of plating on the *Weetamoe*, with a length of six plates on the sheer strake. These plates, though yet in the fastening process, show a high polish, and are devoid, to a great extent, of mar or

dent. The plates have an average width of 42 inches. The heaviest plating, naturally, is at the lowest point—the garboard. Here the weight of the Tobin bronze plates is 6 pounds to the square foot, while on the sheer strake the weight is 5 pounds to the square foot, or about $\frac{1}{8}$ of an inch in thickness, excepting in the immediate overhangs, where the weight of bronze plate tips the scales at $4\frac{1}{2}$ pounds to the square foot.

That the most skilled mechanics are employed in fastening the plates is noted by the fine riveting. The plates at the laps are double-riveted by the so-called chain device, and also at the butts and seams. Diagonal braces, $2\frac{1}{8}$ by $1\frac{1}{8}$ inches, are of Tobin bronze, already fastened, as well as the butt straps. Steel stringers on the sides run forward 22 feet from the stern, while there is a larger one in the center, answering all the purposes of the backbone of a yacht. Of Tobin bronze angles, the gunwale bars are already in place and fastened.

In riveting the *Weetamoe* all precautions were taken to eliminate as far as possible galvanic action, produced by metals dissimilar in character coming in contact with each other where the greatest dampness is expected. So, therefore, bronze rivets were introduced where they will cause the least deterioration to the hull plates, and so also in regard to use of steel rivets in the *Weetamoe's* construction.

The traveler for the main sheet is well fastened to the frames, and is located five feet forward of the exquisite stern; for the foundation of the stern is so finely carried out that it could not well be passed over without such comment.

In the overhangs the connecting plates at the base of the frames are of nickel-steel, forming a steel foundation for the plating at each end, while in every way possible bronze was introduced in the midship section.

The yacht, though an out-and-out racer, will not be lacking in the essentials of comfortable quarters, for provision is made in the design for a cabin about 22 feet in length, including the ladies' cabin and two bed rooms in the after end, the owner's cabin, next forward, entered by a companionway from the deck, and forward of the latter a good-sized saloon cabin. Next for-

ward is a bulkhead, on the other side of which is the skipper's room on the starboard and the galley on the port hand. In the forward section is the forecastle with pipe, folding berths for a crew of eight seamen. Under the cabin floor are the water tanks, with a capacity of 200 gallons. Located over the main cabin is a lavatory, while on the opposite side is the owner's cabin and stateroom. The cabin will have about 6½ feet in the clear for head room. There are, all told, five hatches and skylights, rising slightly above the deck line.

The mainmast buries six feet below the deck and steps on a powerfully constructed steel platform, with special provision for the thrust of the spar if the craft should jump in a seaway. The mainmast will be a hollow spar of Oregon pine set more than a third of the length over all abaft the stem, furnishing a good-sized fore triangle for the new racer.

The deck will be of white pine and will be laid as soon as the blacksmiths finish the work on the floors and mast step. It is believed that the *Weetamoe* will have her plates all riveted in another week, and that she will be ready for launching the latter part of May.

When completely fastened, the plating, now very bright and smooth, will be highly polished.

Weetamoe will have a sail area somewhat greater than that of the sloop *Wasp*. The principal dimensions of the new racer are: Over all, length, 88 feet 6 inches; load-water line, 50 feet 6 inches; breadth of beam, 16 feet 6 inches, and draught, 11 feet. —"Exchange."

OBITUARY.

JAMES JOSEPH BARRY.

Passed Assistant Engineer James J. Barry, U. S. N., died at his home, 106 McDonough Street, New York City, April 30, 1902, from heart and kidney disease.

He was born in Baltimore, Md., November 30, 1841, and was appointed Third Assistant Engineer in the Navy December 8, 1862. He attained the grade of Second Assistant Engineer April 8, 1864, First Assistant Engineer January 1, 1868, and was commissioned Passed Assistant Engineer February 24, 1874.

His service in the Navy till the date of his retirement, January 9, 1891, was about equally divided into sea and shore duty, and comprised the following: 1862–65, steam sloop *Canandaigua*, South Atlantic Blockading Squadron; 1865–66, Navy Yard, New York; 1866–69, Flagship *Pensacola*, North Pacific Squadron; October, 1869, ironclad *Miantonomoh;* November, 1869, to July, 1870, Assistant to Inspector Machinery Afloat, Navy Yard, New York; July, 1870–June, 1871, ironclad *Dictator*, North Atlantic Squadron; 1872–73, Navy Yard, New York; 1873–76, *Juniata*, *Polaris* Search Expedition, Arctic regions, thence joining European Squadron; 1876–77, receiving ship *Colorado*, New York; 1878–79, special duty, New York; 1879–80, *Wachusetts*, South Atlantic and Pacific Squadrons; 1881–83, receiving ship *Colorado*, New York; 1883–86, *Alert* and *Trenton*, Asiatic Station; 1887–April 1889, Navy Yard, New York; 1889–January, 1891, Experimental Board New York yard.

While attached to the *Canandaigua* he saw war service of an important character during the seige of Charleston and attack on Fort Sumter, volunteering for the night assault on the latter. After the detachment of the regular Chief Engineer of the *Canandaigua*, in 1864, he served as Acting Chief Engineer until the close of the Civil War. He also performed other special war duty, in-

volving great danger and calling for, besides personal bravery, no little executive ability and discretion. The outbreak of the Spanish-American war finding him on the retired list, he was detailed for active duty in the Steam-Engineering Department of the New York yard, until its close.

Passed Assistant Engineer Barry was an able engineer, and devoted to his profession. His performance of duty was at all times marked by rare conscientiousness. He was a man of sterling worth and uprightness of character, and through life made his actions conform to a high moral standard. He was a true friend and kindly shipmate, and he was respected and esteemed by all with whom he came in contact. His death caused widespread sorrow in the Naval service.

JOSEPH PHILIP MICKLEY.

Commander Joseph P. Mickley, U. S. N., died at his country home at "Mickleys," Lehigh County, Pa., March 9, 1902. He was appointed Acting Third Assistant Engineer from Pennsylvania on March 28, 1864, and honorably discharged January 11, 1869. He was commissioned Second Assistant Engineer, regular service, March 20, 1871; Assistant Engineer February 24, 1874; Passed Assistant Engineer February 24, 1878; Chief Engineer August 28, 1894; Lieutenant Commander, in the line, March 3, 1899, and was retired January 17, 1900.

Commander Mickley served on *Cour-de-Leon*, Potomac flotilla, Commander Foxhall A. Parker, 1864–5; *Massachusetts* and *Muscoota*, Gulf Squadron, Commander George M. Ransom, 1865–6; *Yucca*, in the relief of the *San Jacinto*, and army transport conveying mails from Havana to Key West; *Resaca*, North Pacific Squadron, Commander J. B. Bradford, at the transfer of Alaska to the United States, 1866–8; honorably discharged 1869. Commissioned, regular service, 1871; monitor *Terror*, Captain S. P. Quackenbush, West India Squadron, rebellion in Cuba, 1871–3; *Lackawanna* and *Ashuelot*, Asiatic Squadron, 1773–6; Washington Navy Yard, monitors *Wyandotte*, *Pasaic* and *Montauk*, during labor riots, 1877–8; special duty, Phila-

delphia, Pa., Assistant to Inspector of Coal, 1878; *Ticonderoga*, Commander B. J. Cromwell, Commodore Shufeldt's expedition around the world, 1878–81; Naval Station, League Island, Philadelphia, Pa., 1881–4; *Powhatan*, North Atlantic Squadron, special duty during the insurrection in the United States of Colombia, 1884–6; Delaware River Iron Works, Chester, Pa., special duty U. S. S. *Boston*, 1886–7; *Yantic*, West India Squadron, 1887; Naval Station, League Island, Philadelphia, Pa., 1888–91; *Fern* and *Vesuvius*, 1891–4; Inspector of Steel, Standard Steel Works, Thurlow, Pa., 1894; U. S. receiving ship *Richmond*, October, '94–August, '95; Inspector of Boiler Tubes, Philadelphia, August, '95–January, '97.

In February, 1897, Chief Engineer Mickley was assigned to the *Terror*, on which vessel he served till near the close of the Spanish-American War. Under the stress and strain of the campaign in the West Indies, his health became so shattered that his detachment from the *Terror* became necessary. Subsequently he was ordered to the Naval Hospital, Philadelphia. Upon his recovery, October, 1898, he was made Inspector of Machinery of the torpedo boats building at the Neafie and Levy Works and the Charles Hillman Works, Philadelphia; but after a little over a year's duty his health proved to be permanently impaired, and he was placed on the retired list, with rank of Commander. His incapacity for active service was found to be directly traceable to the strain which he had been subjected to while attached to the *Terror*.

Commander Mickley was born in Philadelphia, Penna., May 26, 1845. He was a graduate of the High School, of Philadelphia, and, like his father before him, became widely known and esteemed in that city. The same traits and inclinations that marked the father were to be traced in the son. Besides scientific tastes and fondness for antiquarian research, both had a high appreciation of the beautiful. Both through life cultivated the fine arts, especially music, of which they possessed a knowledge approaching that of the virtuoso. In his day, Commander Mickley's father always welcomed to his home, and entertained there, musical celebrities. He gathered together and preserved many articles of vertu, which, upon his death came into the possession

of Commander Mickley. Commander Mickley was himself an enthusiastic collector, and through life added to the historic relics left him by his father. Commander Mickley often dwelt upon the artistic tastes of his father as especially commendable, in this way showing where his own inclinations lay.

Because of these finer instincts and cultivation of mind Commander Mickley had great personal attractions; and because of his genial and generous spirit he was greatly beloved. As an officer he was worthy and patriotic. As a man he was earnest in his affections and true to his kind.

Commander Mickley's funeral took place on Tuesday, March 11th, and the interment was made near his country home in Lehigh County, Pennsylvania. Many officers of the Navy, citizens of Philadelphia, and members of the nearby village community were present. An old-time neighbor of Commander Mickley's was so affected at his loss that he fell dead at his grave, before the earth had covered him in his windowless little house, where he is to sleep for all time among his relatives and friends who loved him so well.

JAMES H. MERRITT.

A few weeks ago there passed out from among those connected with marine engineering and steamship building interests James H. Merritt, of Portland, Maine, late United States Local Inspector of Steam Vessels, being Inspector of Boilers on that Board.

He was born in Portland, Maine, April 1, 1844, and was descended, on both his father's and mother's side, from Revolutionary stock. He was educated in the public schools of Portland, but was allowed only a little of this privilege, being obliged to work at the early age of fourteen years. At this time he secured a position as waiter on a local steamer line between this port and Boston, and here he became interested in the mechanical department of the business, and then determined to make that his life work and profession. Leaving the steamers, he learned the machinist trade, and then, at the age of nineteen, enlisted to serve his country during the days of the Civil War, serving in Company L, First D. C. Cavalry, and Company E, First Maine Cavalry, receiving an honorable discharge at the close of the war.

He then resumed his labors on the steamers, and, securing a position in the engineering department of one of the steamers of the International Steamship Co., plying between Boston, Portland, Eastport and St. John, he advanced himself by hard work and study through the different grades of this department to chief engineer. He served in this capacity for all the large lines between Portland and St. John, Boston and New York. His last license was without limit as to tonnage or capacity of ocean steamship.

After about 25 years' service in the engineering department, he was appointed Boiler Inspector on the Local Board of United States Inspectors of Steamvessels, with headquarters at Portland, filling a vacancy caused by the decease of Charles Staples, Jr., holding same until his decease, November 30, 1901. He had accumulated a fine mechanical library during his studies.

He was sought for advice on construction of marine boilers and engines, and always gave advice and help cheerfully to any who asked. He left a name among all with whom he came in contact honored for uprightness and square dealing, and, by nature, was self-sacrificing and unassuming. A widow and son were left to mourn the loss of a kind and honorable husband and father.

He was an associate member of the American Society of Naval Engineers; a member of Bosworth Post, No. 2, Grand Army; a Thirty-Second Degree Mason, a Mystic Shriner, a Knight Templar, Knight of Pythias, Maine Charitable Mechanic's Association.

CHIEF ENGINEER F. C. DADE.

F. C. Dade, a Chief Engineer of the Navy, on the retired list, died at Philadelphia on the 29th of April. Mr. Dade was a native of Virginia, and descended from Revolutionary ancestors. He received an academic education, and served a regular apprenticeship as a machinist, in which art he was proficient. He was appointed a Third Assistant Engineer October 31, 1848, and made his first cruise on board the sidewheel steamers *Water Witch* and *Saranac*. He was promoted to a Second Assistant in 1851, and served for three years on board coast-survey steamers, where his

services as an engineer and hydrographic draughtsman made him an acquisition. In 1853 Mr. Dade was promoted to a First Assistant, and served a cruise on board the *Saranac* in the Mediterranean. In 1856 he was again ordered to duty under the Coast Survey Office, and in 1857 he was employed on construction and experimental duty with the machinery of the steam frigate *Colorado*. In 1858–9 he was on duty in the Boston Navy Yard, and in 1859–61 he served in the East India Fleet, on board the *Hartford*.

In 1861, the year the civil war began, Mr. Dade was promoted to be Chief Engineer and ordered to the steam sloop *Oneida*, where he remained for three years. During that period the *Oneida* took an active part in the battles of New Orleans, Vicksburg, Port Hudson, Grand Gulf, Baton Rouge, etc., and, being full of resource and energy, he was equal to the emergencies that arose. In 1865–6–7 he was Chief Engineer of the *Canandaigua*, in the Mediterranean; 1866–8 he was on the Board to examine engineers for promotion; from 1869 to '72 he was Chief Engineer at the Norfolk Navy Yard; from 1872 to '74, special duty at Norfolk; and from 1874 to 1877 he was Fleet Engineer in the South Pacific Fleet. Mr. Dade was retired in 1889 after forty years of active service, and from that time lived with his family in Philadelphia.

Mr. Dade was well educated in all that pertained to his profession, art and trade. He was self-reliant and courageous, and a natural leader among men. He was a genial, sunny shipmate, full of anecdote and full of fun. Under the most adverse circumstances he was always cheerful.

He was very domestic in his habits; a devoted husband and father, a genial host in his home, and an entertaining diner-out.

The critical period of Mr. Dade's life was in the breaking out of the Civil War. He was southern born and bred, descended from slave owners and States rights, but he was great enough to see that the best interests of the Republic lay more in an affiliation of the States than in an individuality. This sentiment (if it may be so called) was at its crucial test, and in that supreme moment Mr. Dade decided in favor of the Republic as Washington had installed it, and remained in the cause of the Union.

ASSOCIATION NOTES.

There was a meeting of the Society held at the Navy Department on the evening of April 25 last, for the purpose of opening and counting the ballots for Officers of the Society for the present year, and for the Prize Essayist for 1901; also for the transaction of such other business as might be brought before the meeting.

A resolution was passed directing the President of the Society to appoint a committee of three to prepare amendments to the by-laws.

The result of the election was as follows:

President—Commander Charles W. Rae, U. S. N.

Secretary–Treasurer—Lieutenant Charles W. Dyson, U. S. N.

Council—Commander George W. Baird, U. S. N.; Lieut. Commander Wythe M. Parks, U. S. N.; Lieut. Commander John R. Edwards, U. S. N.

The counting of the ballots for Prize Essayist resulted in favor of the article on "The Coaling of Warships at Sea," by Lieut. Commander John R. Edwards. After authorizing the Secretary–Treasurer to pay the Prize Essayist the amount of the prize, there being no further business before the Society the meeting adjourned.

CHARLES W. RAE, *Commander, U. S. N.*,
President.

CHARLES W. DYSON, *Lieutenant, U. S. N.*,
Secretary–Treasurer.

By request, for the information of our readers, we publish the following program of the IX International Navigation Congress to be held at Düsseldorf, Germany:

The IX International Navigation Congress, under the patronage and personal participation of His Imperial and Royal Highness the Crown Prince of the German Empire, will be held in the Tonhalle at Düsseldorf from 29th June–5th July next. To

judge by the invitations already sent, the coming Congress bids fair to surpass in importance its predecessors, held at Paris, Brussels, etc. The program of exercises shows a rich number of papers by eminent engineers, political economists and learned men, at home and abroad, on questions, partly of an economic, partly of a technical nature, questions which will not fail to excite widespread interest.

In Section I (Inland Navigation) the following subjects are announced for discussion:

1. The surmounting of great ascents.
2. Ship tolls.
3. Depreciation of coal and coke by shipment.

In Section II (Maritime Navigation) the following subjects will be treated:

1. Cost of construction and maintenance of lock gates made of iron or of wood, sluice gates.
2. Sea-lighter-trade.
3. Docks.

In addition to the 41 reports on the foregoing subjects, 41 essays bearing upon the following "Communications" have been announced.

I. INLAND NAVIGATION.

1. Laying out of dams.
2. Mechanically propelling vessels on canals.
3. Draught of river craft less than 75 centimeters.
4. Utilization of water power at weirs.
5. Ships' resistance on canals.
6. New harbors in the Grand Duchy of Baden.
7. The harbor of Crefeld.
8. Hydrographic work in Prussia and Northern Germany.
9. Inland navigation and conjuncture.
10. General view of the management and working of inland waterways.
11. Schemes for canals in Austria.
12. Supply of water for the canals in Austria.
13. Employment of electricity on inland waterways and harbors in Russia.

14. Execution and results of the regulation of the Hunte below Oldenburg.

II. OCEAN NAVIGATION.

1. Flushing of seaports.
2. Protection of lighthouses.
3. Scoop and claw dredging machines.
4. Field of fog signaling.
5. Ship resistance in open water.
6. Dredging at the harbor of St. Petersburg.
7. The Dnieper Ship Canal.
8. The Kaiser Wilhelm Canal (Baltic Ship Canal), 1895–1901. Traffic and experiences.
9. Harbors in the West Coast of Portugal.

Excursions are planned for 1st July, to Ruhrort, Duisburg, Elberfeld and Barmen; 3d July, to the Seven Mts. (Siebengebirge) and Cologne; 5th July, to the Dortmund-Ems Canal, at Herne, Henrichenburg (lifting work) and Dortmund, to Krupp's Works, at Essen, and to the Remscheid Dam and the Emperor William Bridge at Müngsten.

After the Congress an excursion will be made to the Emperor William Canal and the Hansa towns, Bremen, Hamburg and Lübeck. Persons attending the Congress will be hospitably received everywhere.

During the sessions of the Congress an Exhibition of Hydraulics and Navigation is to be held in the adjoining rooms of the Tonhalle, consisting of a display of models, plans and prints of general interest, and especially noteworthy and new.

Great interest is manifested in the Congress on the part of foreign governments, civic communities, chambers of commerce, mercantile corporations, navigation societies, etc., of nearly all European States, including many in Asia and America. This is proved by the sending of official State delegates, the number of whom is likely to amount to 150.

The General Secretary of the Congress, Geheimer Baurath Sympher, Berlin W. 66, Wilhelm-Strasse 80, will be very glad to give any information desired, as well as to send invitations.

ERRATA.

Through an unfortunate mistake in preparing the paper descriptive of the trials of the U. S. Torpedo Boat Destroyer *Decatur*, in the February number of the JOURNAL, the data and description of the condensers and air pumps was that of the *Thornton* instead of the *Decatur*. The following is the correct data, and should be pasted over the inaccurate tables, pages 63 and 64 of the JOURNAL.

H. WEBSTER,
Commander, U. S. N.

CONDENSER.

Diameter of shell, inside, inches	51
Thickness of shell	No. 10 B.W.G.
Tubes, diameter, inch	.625
length between tube sheets, feet and inches	9-3
thickness, No. 20 B.W.G., inch	.035
number in each condenser	2,300
Cooling surface, each condenser, square feet	3,479.9
total, square feet	6,959.8
Ratio, total cooling to total H.S.	.391

AIR PUMP.

Diameter of pumps, inches	12
Stroke of pump, inches	6
Diameter of pump rod, inches	2
Diameter of rock shaft, inches	2½

CIRCULATING PUMP.

Steam cylinder, diameter, inches	4½
Stroke, inches	5
Pump runner, diameter, inches	20
Width at periphery, inches	1.5
Inlet nozzle, diameter, inches	7
Outlet nozzle, diameter, inches	7

The article on page 595 on "Hardening extra-long staybolt taps," should have been credited to "Machinery."